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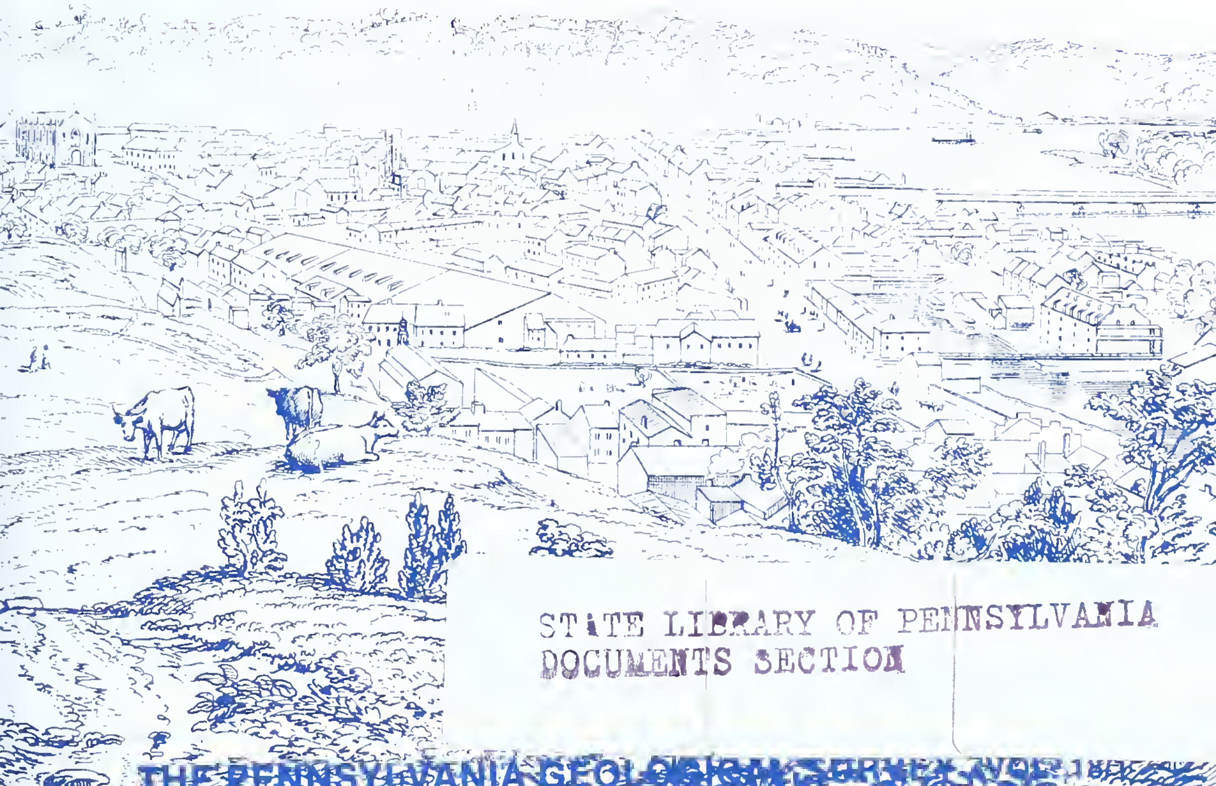
PENNSYLVANIA GEOLOGY

PENNSYLVANIA GEOLOGICAL SURVEY
150TH ANNIVERSARY
1836 - 1986



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TOPOGRAPHIC AND GEOLOGIC SURVEY
Donald M. Hoskins, Director

CONTENTS

This issue is devoted to the history of the Pennsylvania Geological Survey and is the culmination of our sesquicentennial year's activities.

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ON THE COVER: Reproduction of a portion of a copper-plate lithograph entitled "Pittsburgh in 1840, from Grant's Hill," sketched by George Lehman, an artist employed by Henry D. Rogers in the 1840's to illustrate *The Geology of Pennsylvania, a Government Survey,* published in Philadelphia, Pa. in 1858.

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VOL. 18, NO. 1 **FEBRUARY, 1987**

The First Geological Survey of Pennsylvania:

THE DISCOVERY YEARS[1]

by Donald M. Hoskins

The Pennsylvania Geological Survey, known today as the Bureau of Topographic and Geologic Survey, in the Department of Environmental Resources, is one of only a very few Executive Branch agencies whose history can be traced to the first half of the 19th century. Created in 1836, the First Geological Survey was the first of four geologic and topographic surveys active over the past 150 years.

Pennsylvania in the 1830's was a ferment of activity. Population was rapidly increasing, industry was expanding, and anthracite coal was proving useful in the manufacture of iron. Internal developments—the building of turnpikes, canals and railroads—and the creation of a system of Common Schools were the concern of the Governors and Legislators of Pennsylvania. They believed that internal developments and public education were necessary if the resources of the Commonwealth were to be developed.

On March 30, 1836, the General Assembly of Pennsylvania received notice from Governor Ritner that he had signed their bill establishing "a geological and mineralogical survey of the state with a view to determine the order, succession, arrangement, relative position, ... of the several strata or geological formations within the state, and to discover and examine all beds and deposits or ores, coals, clays, marls ...as may be necessary to make a full and complete geological and mineralogical survey of the state." This bill became Act 73 of 1836.

Pennsylvania was the ninth state to enact legislation for a geologic survey and in 1836 joined Georgia, Maine and New York, whose legislative bodies also created geologic surveys in that year.

Created in 1836, the First Geological Survey was the first of four geologic and topographic surveys active over the past 150 years.

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[1] This article is condensed and revised from "Celebrating a century and a half: The Geologic Survey" by D. M. Hoskins which appeared in "Pennsylvania Heritage, Quarterly of the Pennsylvania Historical and Museum Commission," Summer 1986, Vol. XII, No. 3, p. 26-31.

Maryland and New Jersey had previously established geologic surveys in 1833 and 1835, and Pennsylvania's legislative action was not unusual for 1836. The emphasis on internal improvements in Pennsylvania and other States, and the desire to discover usable mineral resources, were all related to the then current concept of mercantilism which held that each state should be broadly involved in the field of economics.

The First Geological Survey began field work in May 1836 and field campaigns were conducted each year until the summer of 1842. Work on the final report was temporarily suspended in 1842 due to lack of legislative appropriations, purportedly due to the State's "financial embarrassments." Field work was resumed in 1851 and eventually resulted in the beautifully illustrated, two volume, quarto-sized report and maps, which were published in 1858.

The beginnings of the First Pennsylvania Geological Survey can be traced to a meeting held September 30, 1826 in the hall of the Franklin Institute, Philadelphia. At this meeting Peter A. Browne, attorney and business promoter, disclosed a plan where he would "make a geological and mineralogical survey of Pennsylvania" and "make a set of geological maps of the state, twenty six in number, upon a comprehensive scale." Although a committee of Philadelphia citizens were formed at the 1826 meeting no further action took place until late February, 1832, when the Geological Society of Pennsylvania was formed. The Geological Society members were to use their influence to have the state geologically surveyed. Memorials prepared by the Society urging the support of a topographic, geologic and mineralogic survey of Pennsylvania were sent to the Legislature of Pennsylvania in December, 1832. A Legislative Committee report was read March 23, 1833 but no action was taken. Additional memorials were sent from the Geological Society of Pennsylvania in December, 1834.

The Geologic Society members were to use their influence to have the state geologically surveyed.

In response to Governor Wolf's 1835 "Message to the Legislature," a Committee of the House of Representatives, chaired by Charles B. Trego, of Philadelphia, read a report of the need to conduct a geological and mineralogical survey and reported a bill for consideration. It is of interest to note that Mr. Trego was to become one of the Survey assistant geologists in 1837 and remained with the First Survey until 1842: he later returned to the House of Representatives. The bill was signed by Governor Ritner on March 29, 1836. Other substantive legislation of that date was an act that authorized calling of a state constitutional convention that convened in 1838.

Thus began the First Geological Survey of Pennsylvania whose investigations and discoveries, when finally published in 1858, after considerable difficulties, were destined to set the geologic framework for all subsequent geologic mapping in the states along the Appalachian Mountains. In addition, the discoveries of the First Geological Survey of Pennsylvania prompted a major new branch of the science of geology-structural geology. This branch of geology is concerned with the form and arrangement of rocks, and their internal structures, and in particular with the description and analysis of the structures.

the discoveries of the First Geological Survey of Pennsylvania prompted a major new branch of the science of geology-structural geology.

Appointed State Geologist of the First Geological Survey was Henry Darwin Rogers, age 26, Professor at the University of Pennsylvania, and employed during 1835 as State Geologist of New Jersey. Joining him as assistants were James C. Booth, age 24, and John F. Frazer, also age 26, both of whom had studied at the University of Pennsylvania. Prof. Rogers' brother, Robert, was appointed Chemist for the Survey.

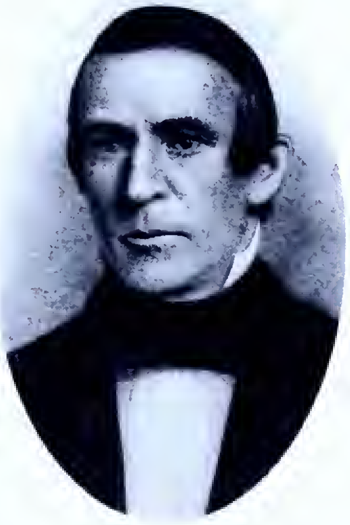
Figure 1. Henry D. Rogers, State Geologist of the First Pennsylvania Geological Survey.

The young geologists proceeded to the field in May, 1836. Prof. Rogers and his assistants made a rapid trip across the state to Erie. This rapid traverse allowed Prof. Rogers to subdivide Pennsylvania into three geologically distinct sections. The Appalachian Section, the middle section, bounded by Blue Mt. on the southeast and Allegheny Mt. on the northwest, was then chosen for the first summer's campaign of field work.

Mr. Frazer went to Bedford County and, starting at Hopewell, where coal was being mined, examined the rocks exposed in the gap of Terrace Mountain and along the course of Yellow Creek through the gap in Tussey Mountain into the limestone valley of Morrison's Cove. Frazer's section began with the youngest rocks, and as he progressed, the section descended through geologic time to reveal that, along Yellow Creek, over 25,000 feet of rock layers of varying character were tilted such that they were vertical, or nearly so, over the whole section. He was thus able to demonstrate that the resistant sandstone layers that underlie Tussey Mountain and Terrace Mountain were in fact, not the same, as had been thought by geologists who had examined the area in previous years. The sandstone and conglomerate layers supporting these mountains were, in reality, separated by many thousands of feet of intervening rock layers. Until this time geologists thought that all of the prominent ridges which make up the mountains of central Pennsylvania were underlain by rocks of the same age.

Professor Rogers, Mr. Frazer and Mr. Booth met in Huntingdon on a Sunday in the summer of 1836 and compared their field notes. Mr. Frazer's Yellow Creek section was disbelieved until confirmed by Rogers later that week in a visit to Yellow Creek. Mr. Booth verified the same sequence of rocks in a traverse along the Potomac River.

The examination of the Bedford County geology in the first year of the Survey, resulted in the conclusion that the coals of the Broad

Figure 2. A quarry in limestone, Consohocken. Sketched by G. Lehman, artist of the First Survey.

Top were of the same geologic position and geologic age as were the bituminous coals known to exist in Clearfield and Lycoming Counties. Previous to Mr. Frazer's section, rocks which underlie the Broad Top and the surrounding areas included in the Appalachian Mountains had been thought to consist of rocks which would include veins of quartz, volcanic rocks and their included metal ores, as well as coal. What they found allowed a profound new scientific understanding of Pennsylvania's geology because it meant that exploration for coal in the rocks of the Appalachian Mountains, except in the Broad Top, was useless inasmuch as no coal existed in these rocks. Where Rogers and his assistants had expected to find in Bedford County ores of metals such as zinc and tin they found instead a profusion of iron ores of the "brown" ore type.

What they found allowed a profound new scientific understanding of Pennsylvania's geology

Rogers and his assistants were also able to subdivide Bedford County's great thickness of rocks into twelve groups of rocks which were easily distinguishable from each other on clearly visible lithologic criteria. The nine oldest groups were given such names as the Cove Limestone, Cove Slate, White Fucoidal Sandstone, and Fossiliferous Sandstone. These nine were further grouped into his Appalachian System. The three youngest groups of rocks were included in the Carboniferous System. During the second year of the Survey Rogers renamed these groups of rocks as Formations and called each by a Roman numeral, from I to XII. This subdivision of formations and the denoting of each formation by Roman numerals, with but few modifications, was used by all geological assistants of the First Survey and by all subsequent Pennsylvania Geological Surveys, until the 1930's, as well as other Geological Surveys of the Appalachian States.

Booth and Frazer did not return in 1837 to do further field work. They were replaced by new assistants, one of whom was Charles Trego, the former legislator. Rogers wrote to his brother, William, State Geologist of Virginia, that "our great and pressing dilemma is for competent geological assistants. The country does not afford them: they are to be made by us..." From 1838 to 1840 a maximum of nine assistants were employed each year; most were trained by Rogers and were sent to various districts in Pennsylvania. The greatest attention was paid to the anthracite and

"our great and pressing dilemma is for competent geological assistants. The country does not afford them: they are to be made by us..."

bituminous coal areas as well as areas in southeastern Pennsylvania where metallic ores were being mined and in the valleys of the Appalachian Mountains where the brown iron ores were found.

Major geologic discoveries made in the subsequent years of the First Survey, were that the anthracite coals were of the same age and origin as the bituminous coals, even though of markedly different chemical and physical characteristics. The use of topography in determining the underlying geology was discovered in 1838, as was the origin of brown iron ores. Dr. Robert Jackson, a physician and later Chief Surgeon of the Army of the Cumberland, was a geological assistant from 1838 to 1841. He studied the brown iron ores of the many limestone valleys in central Pennsylvania and determined that they originated from accumulation of the undissolvable iron resulting from solution of limestone in which the iron naturally occurred. From his and the other assistant's observations in 1838 came the first understanding of the effect of erosion on the earth's surface. Their conclusions were later to be acknowledged and accepted by European geologists.

In 1840 and 1851 Prof. Rogers employed George Lehman and Augustus Dalson, respectively, as artist-draftsmen, who traveled throughout Pennsylvania sketching scenes of the topography and geology. The illustrations accompanying this article are from Lehman's pen and brush.

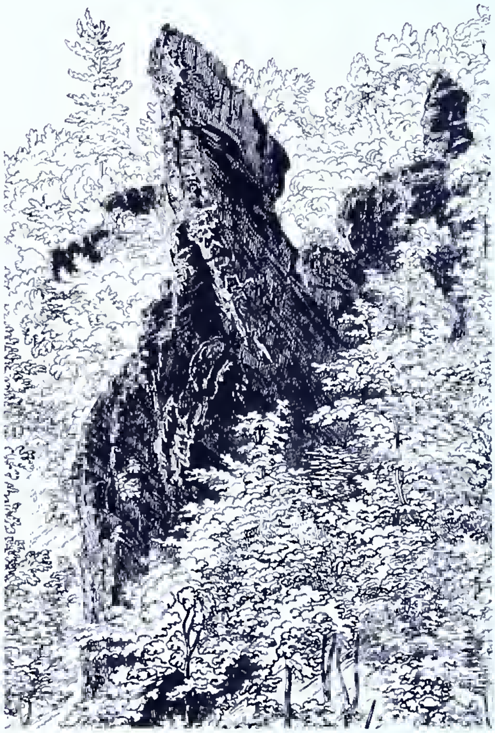

Figure 3. Indian Chief Rock, near Williamsburg, Juniata River. Sketched by G. Lehman, artist of the First Survey.

Field work ended with the 1841 season but the corps of assistants continued work until April 1, 1842. When the Pennsylvania General Assembly did not appropriate funds in 1842, Prof. Rogers was left with no resources to bring the field notes, sketches, section descriptions and maps into order for publication. "Financial embarrassment" of the Commonwealth was the stated reason but perhaps some of the answer for the lack of support could be found in a legislator's comment in 1840. Rogers, in a letter to his brother in Virginia, reported that a Legislator uttered: "Mr. Speaker, I shall vote against this appropriation, on the ground of its unfairness to other sciences of like nature with this geology. The bill, sir, makes no provision for phrenology, physiognomy, animal magnetism, and the highly important science of *water-smelling...*"

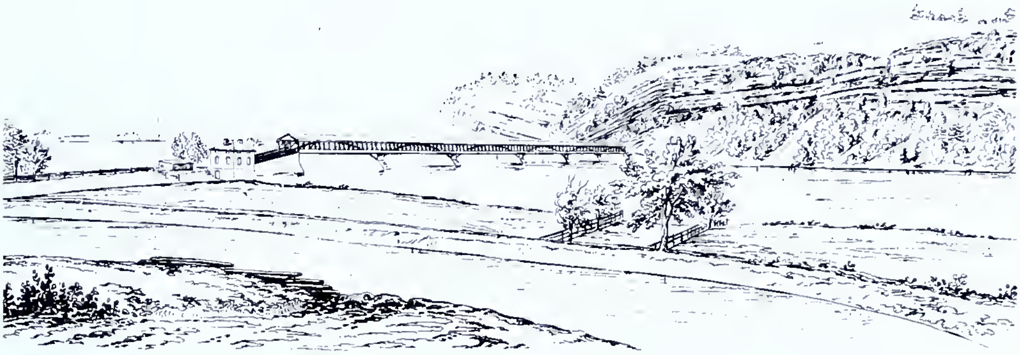

Figure 4. Canal and bridge across the Susquehanna River, with folded rocks, near Northumberland. Sketched by G. Lehman, artist of the First Survey.

A small appropriation in 1843 was apparently used by Prof. Rogers to employ one of the former geological assistants, J. Peter Lesley, (later to be the Chief Geologist of the Second Geological Survey), in the preparation of a set of final maps and reports. They were delivered to the Secretary of the Commonwealth in 1847 for publication. Nothing transpired until 1851 when citizens, particularly in the anthracite regions, clamored for the publication of Rogers' report and maps. Upon their urgings the Legislature appropriated $32,000 of which $16,000 was to be used for publication by "an eminent publishing firm" of Philadelphia and $16,000 for the further work of Prof. Rogers, geological assistants, and miners, in bringing the work up to date.

Additional field work was conducted in 1851 and 1852, largely in the anthracite fields. Prof. Rogers continued work on iron ores, notably the "fossil" iron ores near Danville. He was also engaged in arranging the voluminous individual area descriptions and illustrations, prepared by each geological assistant, into a form suitable for publication, and in writing the summarizations and scientific interpretations for which the final report would become famous throughout the geologic world, in the United States and in Europe.

Rogers proposed in 1855, when all of the materials were ready for engraving and the text for typesetting, that he be given the copyright to the report and maps and the contract for publication. He volunteered to forego his salary in the supervision of the publication process.

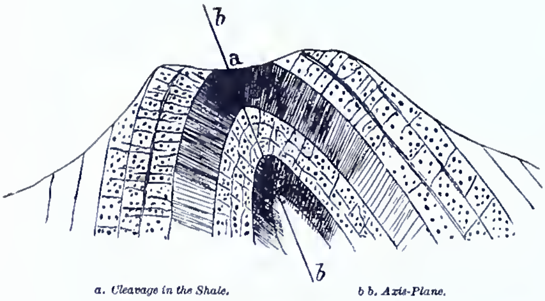

FIG. 715.—Fan-like arrangement of Cleavage at an Anticlinal Axis.

Figure 5. Woodcut illustrating cleavage fanning a fold. Rogers' analysis of such structures as this led to the development of the science of structural geology.

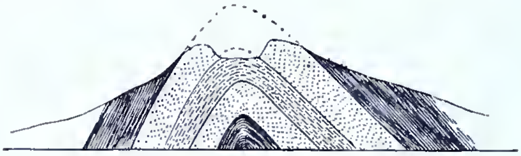

FIG. 740.—Double-crested Anticlinal Ridge, or simple Valley of Elevation.

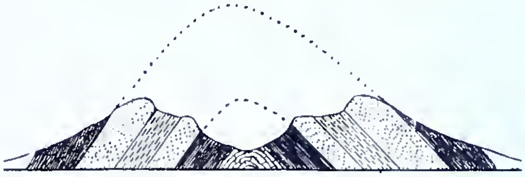

FIG. 741.—Complex Valley of Elevation.

Figure 6. Woodcuts illustrating development of ridges and valleys by erosion. Rogers' synthesis was the first to classify landforms produced by erosion.

Rogers then left for Scotland where he arranged with W. & A. K. Johnston of Edinburgh to engrave the illustrations and maps. William Blackwood & Sons of Edinburgh printed the quarto volumes. They were sold in the United States by Lippincott.

The final report is a magnificent example of the publication processes of the 1850's. It was printed in two quarto volumes of 1631 pages. Included are 778 engraved woodcuts inserted in the text pages. Twenty three engraved plates are devoted to illustrations of fossil plants. Other plates include engravings of geological sections throughout the state and sketches of the scenery and geology along the rivers of Pennsylvania.

Notable for their beauty are the three full-color lithographs bound in the volumes.

With the publication of this beautiful report came the end of the First Geological Survey of Pennsylvania. Soon, however, the demands of the mineral industries, particularly to fulfill the needs of the War Between the States, the discovery of petroleum in northwest Pennsylvania, and the need for accurate geologic maps resulted in the creation of the Second Geological Survey in 1874.

ADDITIONAL READING AND SOURCES OF INFORMATION

Lesley, J. Peter. Historical sketch of geological explorations in Pennsylvania and other states: Pennsylvania Geological Survey, 2nd ser., Report A, 200 p.

Rogers, Henry D., 1858, *The geology of Pennsylvania, a government survey:* Philadelphia, J. B. Lippincott and Company, v. 1, 586 p.; v. 2, 815 p.

________, 1836 to 1842, Annual Reports of the State Geologist for 1836, 1838, 1839, 1840, 1841, and 1842: Harrisburg, Pa.

Rogers, E. S., 1896, Life and letters of William Barton Rogers: Boston and New York, Houghton, Mifflin and Company, v. 1, 427; v. 2, 451 p.

The Second Geological Survey of Pennsylvania

THE GOLDEN YEARS

by Clifford H. Dodge

The discovery and exploitation of mineral wealth in Pennsylvania accelerated during the decade that followed publication of H. D. Rogers' "Final Report" of 1858. Pennsylvania's industrial growth and the discovery of oil prompted public demand for more complete and detailed geologic information about the State's coal, petroleum, iron ore, and other mineral resources. With this in mind, the Pennsylvania Legislature approved a bill on May 14, 1874 to establish the Second Geological Survey of Pennsylvania (1874-1889).[1]

The legislative act creating the Second Geological Survey provided for a ten-man oversight committee (with the Governor, initially, as its *ex-officio* president), or Board of Commissioners, which was authorized to select a State Geologist and to approve all of his plans and major recommendations in operating the Survey. At the first meeting of the Board in Harrisburg on June 5, 1874, it wisely selected J. Peter Lesley (1819-1903) to the post of State Geologist and Director of the Second Geological Survey. Governor Hartranft approved and promptly appointed Lesley, who, at the age of fifty-four, was well prepared for his greatest challenge.

Figure 1. J. Peter Lesley, State Geologist (from a portrait by his daughter, Margaret; in Ames, 1909, v. 1, frontispiece).

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[1] Several different dates—particularly 1887, 1889, and 1895—are commonly given to mark the end of the Second Geological Survey. Although the bulk of the field work was completed by 1887, some continued intermittently, primarily using geologists on a contractual basis, through 1890 and beyond. The last reports of the Second Survey were published in 1895, but the major reduction in activities occurred in 1889 when an act of the State Legislature ordered the work of the Survey in the anthracite fields to cease and the geological assistants to disband by June 1 of that year.

Figure 2. J. Peter Lesley and his wife, Susan, in their parlor at 1008 Clinton Street, Philadelphia, in 1890. Lesley maintained his office here while he was State Geologist. Photograph from Ames (1909, v. 2, facing p. 369).

J. Peter Lesley, a native of Philadelphia, was eminently well qualified and widely respected among his peers. He was professor of geology and mining at the University of Pennsylvania and in 1875 the Dean of the Towne Scientific School. He had been an assistant to H. D. Rogers on the First Geological Survey of Pennsylvania (1836-1842) and was, at the time of his appointment, an acknowledged expert in several fields of geology, particularly coal and petroleum. His broad knowledge of Pennsylvania geology developed during his years with the First Survey and thereafter as a geologic consultant. He was a pioneer, if not the pioneer, in the use of topographic and structure contouring and aneroid altimeters in geologic mapping (Owen, 1975, p. 80-81). Lesley was a respected author of many articles, reports, and publications prior to the organization of the Second Survey. Perhaps most notable were his *Manual of Coal and Its Topography* and *Iron Manufacturers' Guide*, published in 1856 and 1859, respectively. Moreover, he was actively involved with many scientific organizations including the American Association for the Advancement of Science, the American Philosophical Society, and the National Academy of Sciences (of which he was a founding member). Lesley's remarkable life has been discussed at length by Ames (1909), Lyman (1909), and Davis (1915), and his interrelationship with the Second Geological Survey has been examined in detail by Jordan and Pierce (1981) and Chance (1909).

Though subject to its approval, the Board of Commissioners nevertheless gave Lesley wide latitude in planning and executing the work of the Second Survey:

> ...the board of commissioners extended to him [Lesley] the utmost freedom, conferring upon him power to use his own methods, to select his assistants, to determine what work should and what should not be done, relying upon his judgement and ability to produce the best results at least cost, and standing loyally by him as staunch friends and supporters...(Chance, 1909, p. 492).

...the Board of Commissioners gave Lesley wide latitude in planning and executing the work of the Second Survey.

Lesley was firm but fair with his staff, and almost universally respected and admired by them.

In comparing the work of the First Geological Survey with that envisioned for the Second, Lesley (1876, p. viii-ix) wrote that

> the first survey was essentially a reconnaissance. Those engaged in it thirty years ago worked chiefly without instruments of precision and under the greatest inconveniences. Their views were broad, their isolated observations numerous and exact, but their districts never were *accurately surveyed* by them, nor could be. The second survey is intended to supply this lack; to take up their work where they left off; to reduce their general statements to precision; to measure, where they could only estimate; to define, what they could only indicate; to demonstrate what they could see to be true, but which they could not prove and show in all its truth.

There were relatively few trained geologists in the United States when the Second Survey began. Yet, Lesley was able to attract many talented individuals. At the outset, each assistant geologist was

> assigned to a certain district or to special duties, and given one or two [or more] younger men as aids. With these as a nucleus, he [Lesley] gradually built up, chiefly by promotion from among the younger men, a large and efficient corps of trained workers, to whom he accorded the greatest latitude,...holding them responsible only that their work be well and accurately done (Chance, 1909, p. 492).

Many of the inexperienced aides came to the Second Survey almost immediately after graduation from college, but in a year or two were themselves made assistants capable of independent research. Lesley was firm but fair with his staff, and almost universally respected and admired by them. He demanded the highest standards of scientific accuracy and attention to details, which he assured in his added role as editor and proofreader of all Survey publications. His assistants worked hard to please him and, in turn, became better geologists. One cannot help but feel a twinge of envy regarding the mode of operation of the Survey:

> Probably no public organization was ever less bound by the red-tape of officialism than this survey corps, whose members he [Lesley] left untrammelled, unhampered, trusting each other to do his duty, thus placing each in a position where he was driven to do his best, where he would be ashamed to do less (Chance, 1909, p. 492).

Assistants of the Second Survey read like a "Who's Who" in late nineteenth century American geology and included C. A. Ashburner, J. F. Carll, H. M. Chance, E. W. Claypole, J. H. Dewees, E. V. d'Invilliers, Persifor Frazer, Jr., F. A. Genth, T. S. Hunt, Leo Lesquereux, B. S. Lyman, A. S. McCreath, Franklin and W. G. Platt, Frederick Prime, Jr., J. J. Stevenson, I. C. White, Arthur Winslow, and others.

Lesley's style and philosophy pervaded every aspect of the Survey and developed largely as a result of his break with H. D.

Lesley's style and philosophy pervaded every aspect of the Survey...

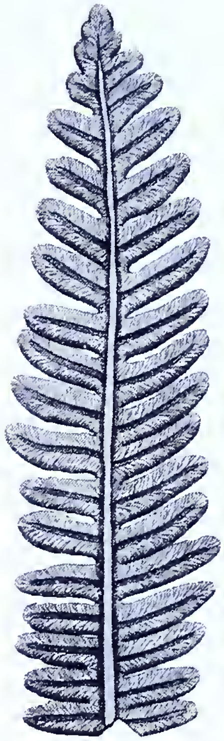

Figure 3. *Callipteridium* leaflets of probable Pennsylvanian age (from Lesquereux, 1879, plate XXXIII, figure 3).

Rogers, who, Lesley believed, failed to acknowledge the specific contributions and ideas of the First Geological Survey assistants. Consequently, "Lesley pointedly used methods at variance with those of Rogers. Where Rogers had amassed draft reports, sketch maps and cross-sections from his assistants for the purpose of publishing a definitive final report, Lesley published reports from each district or project as soon as the material could be assembled and edited" (Jordan and Pierce, 1981, p. 75). In this way, the results of the Second Survey were more useful and timely, and their value to the public was continually made apparent. In addition, Lesley made certain that his assistants always received proper credit for their authorship and ideas.

Merrill (1924, p. 495) once described the publications of the Second Geological Survey as "the most remarkable series of reports ever issued by any survey." During the two decades that it operated, the Second Survey published nearly 120 atlases and volumes, comprising numerous maps, drawings, columnar sections, and cross sections and more than 25,000 pages of printed matter. In addition, it produced a "Grand Atlas" (in six parts) and a geologic map of Pennsylvania (scale, 1 inch = 6 miles). The publications of the Survey are practical and not theoretical, a condition imposed by Lesley. The reports generally contain detailed descriptive information on the geology of the various counties or districts. The atlases provide much supplemental material.

Although the maps and illustrations were intended to be utilitarian, many are truly works of art. One need only glance at the lithographs of the fossil coal flora (Lesquereux, 1879) or the Olean Conglomerate

Merrill once described the publications of the Second Geological Survey as "the most remarkable series of reports ever issued by any survey."

(Ashburner, 1880) to appreciate the beauty of the workmanship. Some of the most striking yet accurate geologic maps of the Second Survey were prepared for the anthracite coal fields, where more detailed information was available (see Dodge, 1981, p. 90-91). The use of multiple colors on these maps to distinguish surface and subsurface features was unsurpassed at that time by any other State surveys or the newly formed U.S. Geological Survey. Examples such as these can be repeated many times.

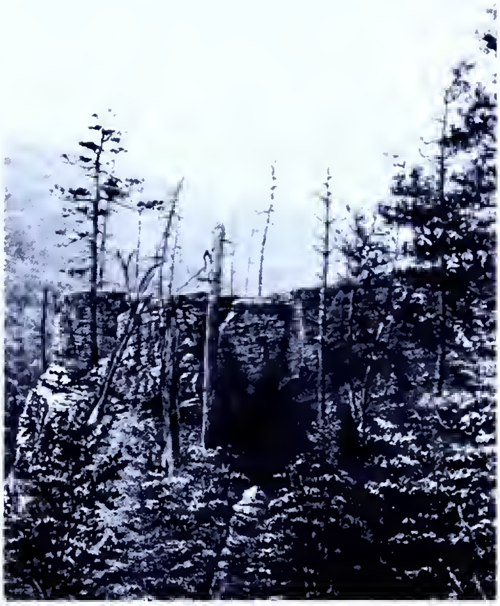
Figure 4. Type locality of the Olean Conglomerate, Rock City, Cattaraugus County, New York (from Ashburner, 1880, plate I, facing p. 50).

The Second Geological Survey contributed much to our understanding of the geology of Pennsylvania. It established the rock stratigraphy of the State

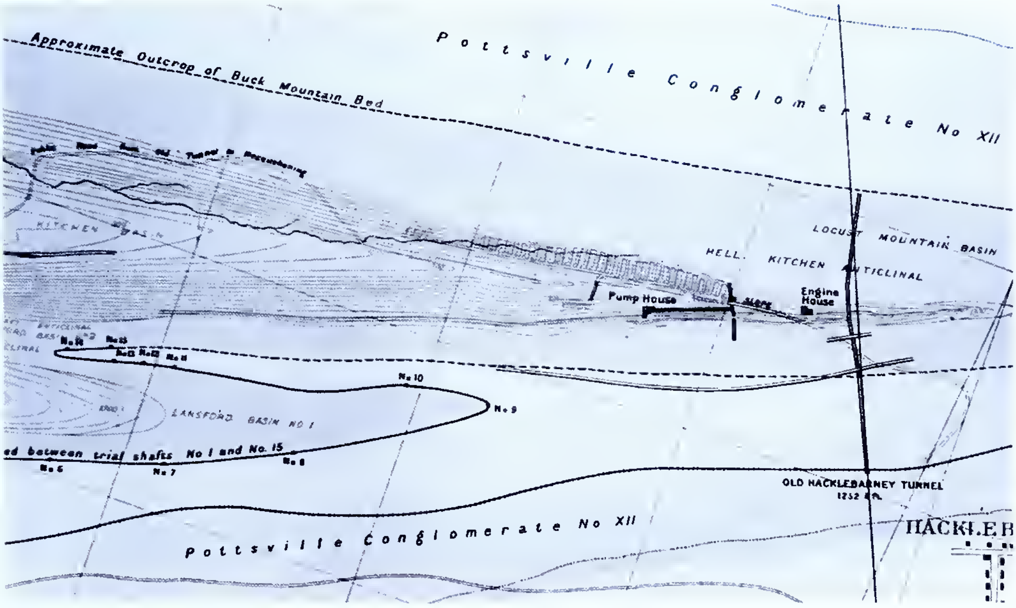

Figure 5. Example of the early use of structure contours, portion of mine sheet 1, Panther Creek basin, Southern Anthracite field (from Ashburner, 1882).

and much of the stratigraphic nomenclature still in use today. It published geologic maps for all 67 counties. The Geological Survey was particularly successful in its correlation studies in the coal and oil regions of western Pennsylvania. It achieved international acclaim for its unprecedented detail and precision in mapping the geology of the anthracite mining districts. During its anthracite studies, conducted between 1880 and 1889, it began the first large-scale, systematic use of structure contours (Dodge, 1981, p. 90), and it constructed a number of topographic base maps on which to compile the extent of deep mining. Even though its paleontological studies were subordinate to its main objectives (i.e., mineral-resources investigations), the Survey received considerable praise for its reports on the fossil coal flora.

Despite all of its success, the Second Survey was not free of difficulties or criticism. One constant source of frustration was the uncertainty of renewal of its biennial appropriation. This created problems when trying to plan future activities and led to resignations of staff who wanted stable employment at a good salary. By the mid-1880's, criticism from the Pennsylvania Legislature grew concerning publication costs, the number of volumes produced, and "the amount of relatively undigested and repetitious material presented in the many volumes" (Jordan and Pierce, 1981, p. 83). These factors ultimately led to the demise of the Second Survey. By the time it ended, the Survey had spent almost two-thirds of its entire budget of nearly $1.6 million on publishing; the other third went to office and field expenses, as well as salaries (Jordan and Pierce, 1981). Nevertheless, when referring to various Second Survey publications, it is the vast amount of information that they contain that make many of them useful even today!

The lack of accurate topographic base maps is often cited as "the fundamental defect" of the Second Geological Survey (Merrill, 1924, p. 496). The implication, however, that the Second Survey did not recognize the importance of topographic mapping is incorrect. Rather, it was the Pennsylvania Legislature that remained unconvinced about the importance and urgency for this type of mapping and that failed to appropriate the funds repeatedly requested by the Second Survey for statewide topographic work. From the start of the Survey, Lesley and members of his staff tried to demonstrate both the need and value of topographic maps. Time and money permitting, the Survey undertook its own topographic mapping, initially for topical studies and later in conjunction with geologic mapping in the anthracite fields. As early as 1884, the

By the time it ended, the Survey had spent almost two-thirds of its entire budget of nearly $1.6 million on publishing...

U. S. Geological Survey and U. S. Coast and Geodetic Survey offered to participate in a cooperative program with Pennsylvania for the purpose of conducting comprehensive topographic and triangulation surveys of the State (Lesley, 1886, p. xxxviii-xxxix). The Board of Commissioners endorsed the proposal, but the Legislature did not. Thus, the proposal failed, even though the State would have had to contribute only about 20 percent of the money needed for the program. In 1888, as part of its cooperative program with New Jersey, the U. S. Geological Survey began to map the topography of the Pennsylvania portions of the 15-minute quadrangles that also extended into New Jersey. Thereafter, at the urging of Lesley, the U.S. Geological Survey undertook some topographic quadrangle mapping in the anthracite fields and adjacent areas in southeastern Pennsylvania (Powell, 1890). However, systematic, statewide topographic surveys did not begin until the cooperative agreement between Pennsylvania and the U. S. Geological Survey was finally signed in 1899 (see Sevon, this volume).

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The Third Geological Survey of Pennsylvania:

THE TOPOGRAPHIC YEARS

by W. D. Sevon

J. P. Lesley, director of the Second Pennsylvania Geological Survey, commented in 1876 (p. 112-113), "In its very nature a geological survey is continuous ad libitum, and should be perpetual. Its first stages are rapid and of the nature of a reconnaisance, or general survey of the country to be afterwards better surveyed. As it advances it discovers its own future work and prepares to do it. The longer it lasts the more local, special, exact and important it becomes." This sentiment was reiterated by the Commissioners of the Second Survey in 1892 when they said: "The work of a geologial survey is never done in one sense...new discoveries are continually being made. Such discoveries should...be subjected to investigation by competent experts...the geological survey should be made a permanent bureau." The commissioners went on to emphasize the need for topographic mapping as well as geological studies (McNees and others, 1906, p. 44). However, the admonitions were not heeded. Field work of the Second Survey ended in 1887 and the final volume was published in 1895. Continuity in Pennsylvania geologic investigations was once again broken.

> "The work of a geological survey is never done in one sense...new discoveries are continually being made."

THE THIRD SURVEY

The Third Pennsylvania Geological Survey was established as the Topographic and Geologic Survey of Pennsylvania by Legislative Act approved by Governor William A. Stone on the 28th day of April, 1899. The act established a commission of three unpaid citizens to confer and accept cooperation with the United States Geological Survey for the purpose of preparation and completion of contour topographic and geologic maps of the state. The sum of $20,000 was appropriated for each of the first two years of the survey; G. W. McNees, Simon Harrold, and Fred D. Barker were appointed commissioners; and contractual agreement with the U.S. Geological Survey was signed on July 12, 1899.

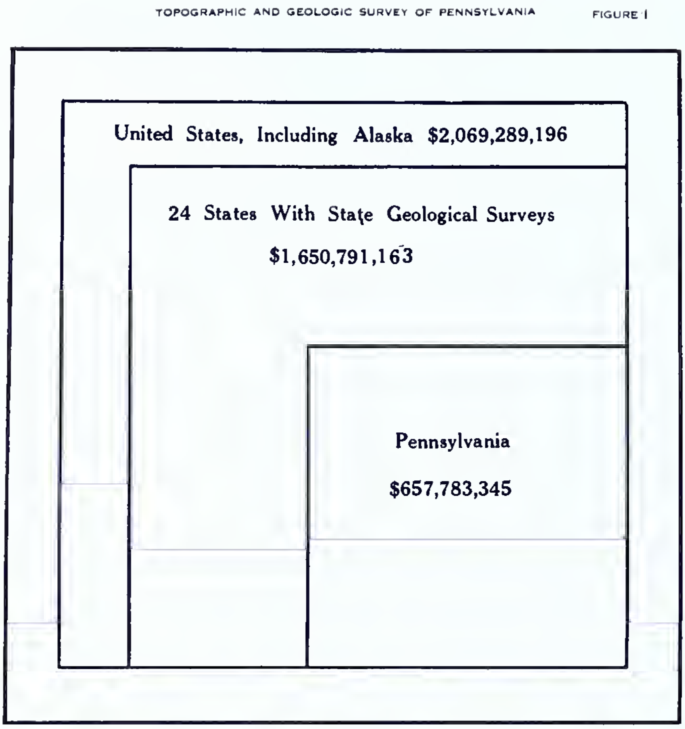
A legislative enactment of May 13, 1909 signed by Governor Edwin S. Stuart authorized the establishment and maintenance of a topographic and geologic survey of the State and the appointment of a State Geologist with an annual salary not to exceed $3000. Provisions were made for publication of reports, deposition of specimens in the State Museum, and the lawfulness for survey employes to enter upon and cross all lands. The act called for an appropriation of $20,000 per year, but only $10,000 per year was allowed because of "insufficient State revenue." Richard R. Hice was appointed State Geologist.

Figure 1. Richard Hice, State Geologist of the Third Pennsylvania Geological Survey.

Hice, a brick manufacturer and founder of the American Ceramic Society, maintained his office in Beaver and directed Third Survey efforts primarily towards coal, gas, and oil. His philosophy was (Hice, 1912, p. 156): "The primary purpose of a Geological Survey is the encouragement of the mineral production of the State." In 1911 he entered into agreement to cooperate with the U.S. Geological Survey in collection of the mineral statistics of the State, a cooperative effort which still exists.

Money for geologic and topographic work never flowed like water from the Pennsylvania legislature. McNees and others pointed out in 1910 (p. 22-26) that the relative value of mineral products in the United States, including Alaska, was $2,069,289,196 of which $657,783,345 was produced by Pennsylvania. But while Pennsylvania had nearly a third of the mineral products wealth of the United States, it was spending for geologic and topographic work only one dollar for each $65,700 of the annual mineral products. This contrasted to the one dollar being spent for each $2,440 in New York and for each

"The primary purpose of a Geological Survey is the encouragement of the mineral production of the State."



Relative Value of Mineral Products of the United States, Including Alaska; of 24 States with State Geological Surveys and of Pennsylvania.

Figure 2. Value of Pennsylvania's Mineral Production compared to other States and the U.S. during the Third Survey.

$1,989 in New Jersey. In 1914 (p. 20-21) Hice showed that Pennsylvania had a mineral production value of $9,981 per square mile, almost twice that of the second richest state, West Virginia, but spent only $0.33 per square mile on geologic work. It appears that these statistics had little or no effect on the Legislature. During the existence of the Third Survey less than $250,000 was spent by the State for topographic and geologic work.

There are no administrative or legislative records about the Third Survey after 1914. No publications ensued and there is no indication that the Legislature appropriated any money for the Survey. Limited correspondence on file at the present Survey indicates that Hice still maintained an office in Beaver when Ashley was named State Geologist of the Fourth Survey in 1919. Hice apparently shipped some Survey materials to Ashley in Harrisburg. The Commissioners also had an office in Harrisburg in 1919, but there is no record of the disposition of the Commissioners or any Survey items which may have been in their possesion.

THE SURVEY WORK

The U. S. Geological Survey was already involved in various topographic and geologic projects in Pennsylvania when the Third Pennsylvania Survey was created. However, an increased amount of field work was possible with the additional money provided by Pennsylvania and the equal dollars matched by the U. S. Geological Survey. The cost of publication and the responsibility for scientific control of those projects was borne by the Federal Survey. The order in which the work was done was determined by mutual agreement. M. R. Campbell was the supervisor in charge of Pennsylvania geologic work from 1900 to 1904 when George H. Ashley, then a U. S. Geological Survey employee, took charge until 1910.

Geologic work during the first cooperative year included mapping the Uniontown and Masontown quadrangles as well as the Gaines and Elkland quadrangles. These were published as part of the geologic folio series by the U. S. Geological Survey. Of particular note is the field season of 1902 during which time A. C. Roberts went to the Houtzdale quadrangle and "made numerous notes on the geologic features, including the location of several faults, and prepared a preliminary areal geologic map." (McNees and others, 1908, p. 100). Work continued intermittently in this area for more than half a century before reports were finally published in 1968 (Edmunds) and 1977 (Glass and others) by the Fourth Survey.

Work continued intermittently in this area for more than half a century.

Most of the geologic work was done in the western part of the State and was oriented almost exclusively toward economic resources. Numerous reports were published by the U. S. Geological Survey during the existence of the Third Survey and 17 volumes totalling 3200 pages were published by the Third Survey itself. One of the most important works published was a report on the Broad Top coal field (Gardner, 1913) which still remains the primary source of information about this area. Among the geologists who worked in Pennsylvania during the Third Survey cooperative era were several whose work was prominent during the Fourth Survey era: G. H. Ashley, C. Butts, M. R. Campbell, B. L. Miller, R. W. Stone, and G. W. Stose. However important the geologic work was, equally important work was accomplished by the less heralded topographic mappers.

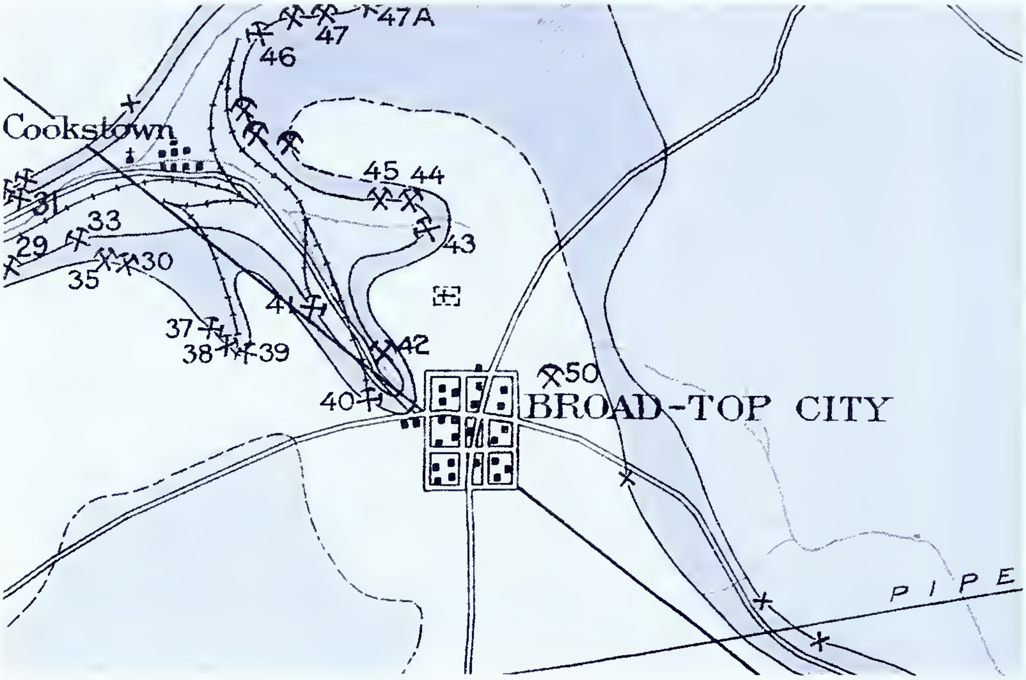


Figure 3. A portion of the Geologic Map of the Broadtop Coal field.

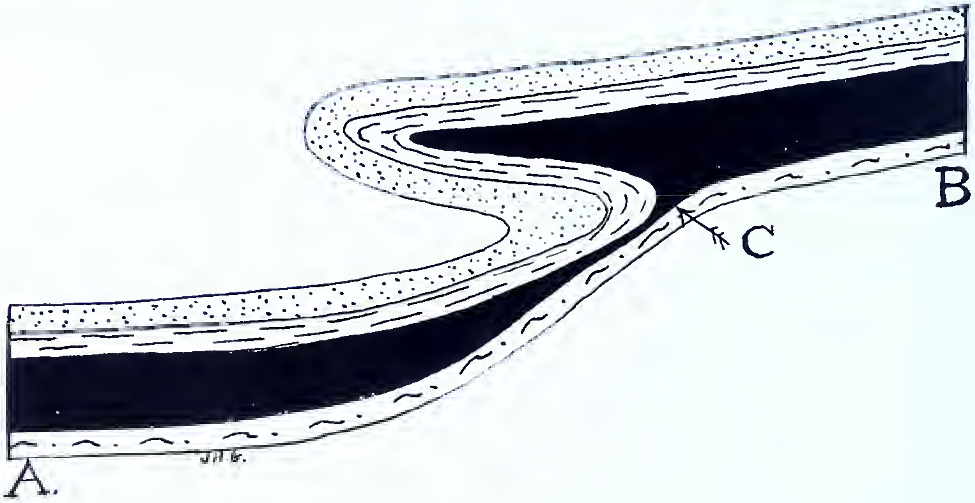


PLATE XXV.

Figure 2.—Sketch, showing manner in which a "split" is produced by an over thrust roll. Illustrated by local conditions in Jrdith and Rock-bar Mines.

Figure 4. Cross sections of the coals in the Broadtop Coal basin showing the complexities encountered by mappers of the Third Survey.

The value of the topographic mapping cannot be overemphasized. Lesley (1876, p. 115-116) pointed out that one of the great problems of the First Survey was the lack of a base map: "The best county maps extant at that time were very imperfect, and as for the State map published by Melish, it was a wilderness of blunders more or less absurd...As a topographical or geographical statement all the northern and western half of Melish's map was simply a monstrous misnomer." The Melish map had been authorized by the Legislature by an act approved in 1816 and was issued in several editions in the 1820's and 1830's. Lesley reiterated his complaint about the lack of a Legislature supported map in 1886 (p. xxxvii-xxxix) because the Melish map was still the only map available, and decried the fact that a cooperative agreement with the U. S. Geological Survey for topographical mapping had not been arranged as recommended by the Board of Commissioners in 1885. The Third Survey resulted from pressure on the Legislature when enough people of the State appreciated the desirability of having an accurate topographic map of the State and the economic value of a cooperative arrangement with the U.S. Geological Survey.

Procedures for topographic mapping were well established by the U. S. Geological Survey prior to 1899. Triangulation stations within Pennsylvania already astronomically located by the U. S. Coast and Geodetic Survey or the U. S. Lake Survey made such work unnecessary by the U. S. Geological Survey. The topographic mappers created baselines through triangulation, set primary traverses with theodolite measurements, did secondary traverses along roads by buggy or buckboard using the revolution of the wheel to measure distance, determined many elevations by leveling or aneroid barometer, and used the plane table to fix the position of large numbers of points. The most important part of the map making, sketching in the details, was generally the work of the chief of the party. "Sketching is artistic work, some men seem to have the native ability for it, to others it only comes as the result of time and hard work, and still others may fail to acquire it." (McNees and others, 1906, p. 36).

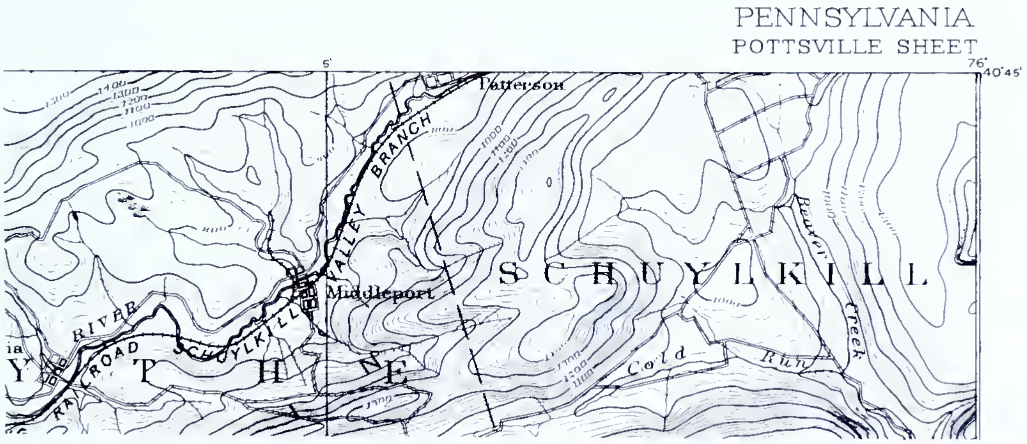


Figure 5. A portion of the Pottsville 15 minute topographic map, the first topographic quadrangle map of a part of Pennsylvania.

The Third Survey is best honored for the successful implementation of the cooperative Federal and State topographic mapping program which exists today for the benefits of the people of Pennsylvania.

The topographic maps produced were at a scale of 1:62,500 (15' quadrangles) and had a contour interval of 20 feet. These maps portrayed accurately for the first time the topography and position of natural and cultural features throughout the State. The first Pennsylvania 15' quadrangle was the Pottsville sheet surveyed in 1889 and published in 1891. The production of these maps continued into the late 1950's. The slow and tedious field methods were replaced by photogrammetric methods after the Second World War. Mapping at the currently popular scale of 1:24,000 (7½′ quadrangles) commenced in 1944, was completed in 1971, and is now periodically photo-revised. Compilation of the 1960 Geologic Map of Pennsylvania was done on the 15′ topographic quadrangles; that of the 1980 map on the 7½′ quadrangles. The immensely more obvious relationship of topography to rock lithology shown by the 7½′ quadrangles greatly increased the precision of contact location during the latter compilation. The Third Survey is best honored for the successful implementation of the cooperative Federal and State topographic mapping program which exists today for the benefit of the people of Pennsylvania.

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The Fourth Geological Survey of Pennsylvania:

THE RESOURCE YEARS

by Rodger T. Faill

Geological knowledge of Pennsylvania had been greatly advanced by the Second Survey, but the need for additional information persisted. The Third (Commission) Survey's concentration on topographic mapping did little to satisfy this need and led in 1914 to the lapse of appropriations by the Pennsylvania Legislature. But the need was still there, and five years later the Legislature established a fourth survey with a broader mandate. On June 7, 1919, the present Topographic and Geologic Survey was created as a bureau within the Department of Internal Affairs, and on September 1 of that year, George H. Ashley assumed the office of State Geologist.

Perhaps the main reason the Fourth Survey has persisted and grown is because its objective has been one of continuing service to the Commonwealth in particular, and the geological community in general. The first two surveys had the limited objective of producing a single series of reports. When these objectives were accomplished, the Surveys were disbanded. The primary objective of the Third Survey was to produce topographic maps (in cooperation with the U.S. Geological Survey). Beyond this, it did not have well defined goals and was never able to mount and sustain a vigorous program in geological activity. In contrast, the Fourth Survey was em-

Figure 1. George H. Ashley, first director and State Geologist of the Fourth Pennsylvania Geological Survey (1919-1946).

powered to "undertake, conduct, and maintain...a thorough and extended survey of the State for the purpose of elucidatating the geology and topography of the State." The enabling act spelled out a large number of activities, including locating and analyzing all types of minerals, resources, and useful rock formations, maintaining collections of samples, formation of a library, cooperation with state and federal organizations, and perhaps most importantly, publishing its results.

THE EARLY YEARS

It was natural that George Ashley was named State Geologist of the newly created Fourth Survey because he had worked in Pennsylvania, and with coal, for the first two decades of this century. He had been State Geologist of Tennessee for two years, but most of his prior experience had been with the U. S. Geological Survey, most recently as Chief of the Coal Section, where he supervised the coal projects in the eastern part of the United States. In a way it is ironic (or perhaps fitting) that one so involved in coal should start in 1919, for in the midst of the economic upheavals following World War I, a major nationwide coal strike had closed most of the industry.

But it was in natural gas, not coal, that the new survey made its first mark. The McKeesport gas field was discovered in August of 1919 and it promised to be a rich field. Ashley soon visited the area, and despite his warnings that excessive drilling would lead to large losses, drilling proceeded at a rapid pace. Within two years the overdeveloped McKeesport field was largely depleted. Ashley's interest in oil and gas may also be reflected in the fact that the first map produced by the Survey was one showing the locations of the oil and gas fields.

Coal, on the other hand, was not to be ignored. The uncertainties in supplies caused by the miners' strikes gave impetus to search for alternative sources. This underlay Ashley's instigation of culm bank and river coal studies. And the Highway Department's need for limestone as road building material in northwestern Pennsylvania was also an early focus for the new organization.

Responding to the immediate needs of the Commonwealth was and still is a primary responsibility of the Geologic Survey, but Ashley recognized that a more systematic program was needed to answer future needs. Foremost in Ashley's overall plan was to produce a new Atlas of Pennsylvania, comprising both a topographic and a geologic map of each quadrangle. A start had already been made. Mapping was being actively pursued, not only by U. S. Geological Survey geologists (e.g.,

Foremost in Ashley's overall plan was to produce a new Atlas of Pennsylvania.

Charles Butts, M. R. Campbell, George W. Stose, and M. J. Munn), but also by academics (e.g., Florence Bascom, Eleanora Bliss, and Benjamin L. Miller). Their efforts were concentrated in the crystalline rocks in the southeastern part of the state, and the coal measures of the Carboniferous and Permian rocks of southwestern Pennsylvania.

Ashley needed a staff to carry out such an ambitious mapping program—by the end of the first year, he had hired four geologists and five support staff. Ten years later the number of geologists had grown to nine, a size at which the survey remained through the ensuing 25 years. One of the better known staff members was Bradford Willard, a paleontologist and Devonian expert throughout the 1930's and 40's. Another staff member was Ralph W. Stone who wrote, among other reports, *Building Stones of Pennsylvania*. In the 1920's, Charles H. Behre extensively studied the slate industry in Pennsylvania. Marchant N. Shaffner produced 3 atlases in the bituminous coal district. Anna I. Jonas worked through the 1920's and 30's in southeastern Pennsylvania and was, along with Stose, an enthusiastic and vociferous proponent of the overthrust concept as applied in the Piedmont and Reading Prong.

But, as effective as this staff was, it was not enough, and in the early years of the Fourth Survey, Ashley contracted with 13 cooperating geologists to produce geologic maps. These geologists including such luminaries as Bascom, Miller, Edgar Wherry, and Charles Fettke. Cooperative projects with the U.S. Geological Survey involved Stose, Munn, Richardson, and Johnson, among others.

including such luminaries as Bascom, Miller, Edgar Wherry, and Charles Fettke.

Not having topographic maps (which provide an accurate base) was a major disadvantage under which the Second Survey worked, and this may explain Ashley's intent on completing the topographic mapping of the state as soon as possible. When he took office, only 56 percent of the state had been mapped and thus the choices for geologic mapping were somewhat restricted. As a consequence, Ashley continued the cooperative program with the U.S. Geological Survey (see Sevon, this issue), in which the federal survey produced the maps, and the state shared in the costs.

Dissemination of the geologic information is as important as the gleaning of it from the rocks, soils, and landscape, a fact that was thoroughly understood by Ashley. However, publishing at first was frustrated by a very slow state printing office, so much of the early material was issued in mimeographed form. By the end of the survey's first decade, nearly 100 of these Bulletins (now called Progress Reports) had been printed, along with 6 Atlases and 12 Mineral Resource reports, which included coal (both bituminous and anthracite), lead and zinc ores, oil and gas, slate, fire clays, limestones, and silica refractories.

In lieu of a completed Atlas of Pennsylvania, Ashley planned a single geologic map of the entire state which was finally published in 1931, done largely by cooperative geologists (Stose and Ljungstedt, 1931). Much of this map was taken directly from the work of the Second Survey, but it also included the new work in the crystalline terrane of southeastern Pennsylvania, and the extensive mapping in the bituminous fields in the southwestern portion of the state.

Ground water is the principal source of much of the water that is used in Pennsylvania, a fact not lost on Ashley. In 1923, a cooperative program with the U.S. Geological Survey was initiated to ascertain the ground water resources for the entire state. Six regional reports, and a state-wide report, were completed over the next 18 years, volumes that are still in use today.

George H. Ashley retired from the Pennsylvania Geological Survey on August 31, 1946, ending a 27 year career as State Geologist. By this time the topographic mapping of the state at the 1:62,500 scale was nearly complete. His plan for an Atlas of the entire state was much further from fruition, but geologic mapping is perforce a much slower activity. Even so, eleven atlases and six county reports were published, along with 19 general geology reports, 27 on mineral resources, 7 on ground water, and 130 progress reports.

INTERREGNUM

Stanley H. Cathcart was the next State Geologist, taking office on January 1, 1947, at the end of Ralph W. Stone's largely ceremonial four months as chief geologist of the survey. Cathcart's earliest experience, with the U.S. Geological Survey, was in metalliferous geology, but his subsequent years in overseas oil exploration with several oil companies provided him with a strong background when he joined the Fourth Survey in 1938.

Oil and gas studies had been an important part of the Survey's activity over the years, in which Cathcart had been an major contributor. Charles Fettke continued his studies, particularly on the Bradford oil field. Innummerable wells have been drilled for oil, and more

Cathcart instituted a series of annual reports listing the data from the recently drilled deep wells.

recently for gas, since 1857, when Drake spudded the first producing well in the United States. Since the inception of the Fourth Survey, an effort has been made to record the locations and characteristics of every petroleum well drilled in Pennsylvania. So many relatively shallow wells have been drilled over the years that publishing the data on all of them would be of little interest to most geologists. However, as drilling reached deeper unexposed formations, interest in these deeper wells has increased. In 1950, Cathcart instituted a series of annual reports listing the data from the recently drilled deep wells. Also begun at this time was an annual report on the production of minerals in Pennsylvania. Both of these reports have continued as important contributions to the Survey's information output.

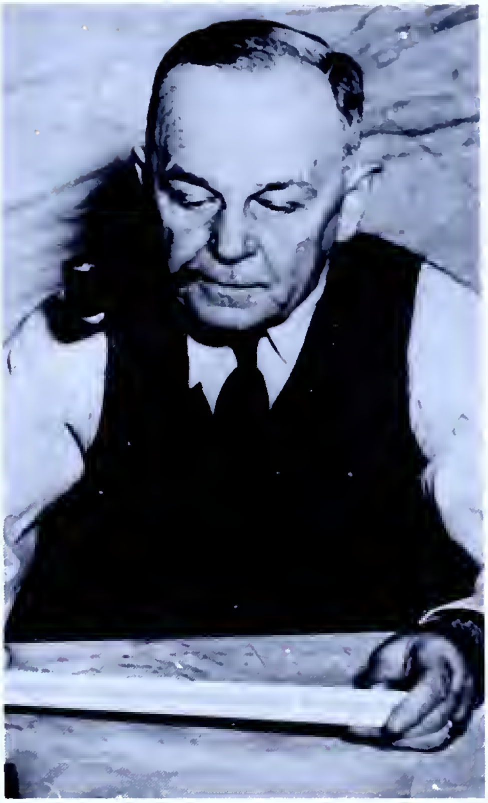


Figure 2. Stanley H. Cathcart, second director and State Geologist of the Fourth Pennsylvania Geological Survey (1947-1953).

Stanley Cathcart died in 1953. Ralph Stone once again stepped in as acting State Geologist for seven months until the next State Geologist was appointed.

REORGANIZATION

Carlyle Gray, a member of the staff since 1949, became acting State Geologist in October of 1953, and was formally appointed as State Geologist in October, 1955. It was during this time that a change in focus and structure of the Pennsylvania Geological Survey occurred, with new objectives being defined.

The depression and the ensuing war years had brought most of the quadrangle mapping in Pennsylvania to a halt. Finally in the mid-1950's, a determined program of Atlas mapping was restarted at the instigation of Carlyle Gray. Perhaps most important was the change of mapping scale to that of the new 7½ minute series of topographic maps. Mapping at this larger, 1:24,000 scale permitted much greater detail and accuracy, and has been standard since.

Figure 3. Carlyle Gray, third director and State Geologist of the Fourth Pennsylvania Geological Survey (1953-1961).

The carbonates of the Great Valley in Lebanon County were the first target because of their importance to the steel industry that was present and growing there. It was also decided to map two corridors across the Valley and Ridge province, one north-south and the other east-west because so little work had been done in the central part of the state. Mapping in the bituminous fields (which had occupied so much effort in the early part of the century) was continued, centering on Clearfield County.

Mapping was not the only activity that accelerated during the latter part of the 1950's. An extensive study on the Cornwall iron mines was commenced, along with a variety of other geologic subjects: the geology of Bucks County; chromite mining; paleontology of the Bloomsburg Formation; and the glacial geology of northwestern Pennsylvania.

Two new volumes were brought out in the late 1950's, designed for the amateur as well as professional geologist. These two volumes, *Mineral Collecting in Pennsylvania* and *Fossil Collecting in Pennsylvania,* describe the locations where minerals and fossils can be collected in Pennsylvania. They are the Survey's two perennial 'best sellers', and have been revised and updated a number of times over the years.

The most recent geologic map of the state at this time was by Stose and Ljungstedt (1931), much of which was based on Second Survey work. Gray did not want a new version to be based on such dated material, but despite all the work the Fourth Survey had done up to that time, large areas of the state had not been evaluated since before the turn of the century. Accordingly, the entire geologic staff reconnaissance mapped the entire state, and compiled the new data on 15-minute quadrangle maps. From these maps, a new geologic map (Gray and others, 1960) was assembled, more detailed and colorful than any of its kind before.

a new geologic map... was assembled, more detailed and colorful than any of its kind before.

Ground water studies in Pennsylvana tapered off in the early 1940's. A few reports were published in the next ten years, but it wasn't until the late 1950's that studies on ground water became widespread across the state. Since then a steady stream of ground water reports have appeared, for specific formations, for quadrangles and counties, and specific lithologies.

With Carlyle Gray's resignation in September, 1961, Alan R. Geyer stepped in as acting State Geologist for the next three months.

GROWTH TO THE PRESENT

Arthur A. Socolow was named State Geologist at the end of 1961, having worked at the Pennsylvania Geological Survey since 1957. During the ensuing 25 years, the Survey continued to grow, and expand its activities into new areas of research and evaluation. Throughout most of its history, the Fourth Survey was a bureau within the Department of Internal Affairs. In 1971, the Topographic and Geologic Survey was transferred to its present administrative home, the Office of Resource Management of the Department of Environmental Resources.

Geologic mapping has remained the cornerstone of the Fourth Survey's activities. The study of the carbonates in the Great Valley in eastern and south-central Pennsylvania continued. During the 1960's and 70's, mapping in the Valley and Ridge province in central Pennsylvania focused on the major population centers of Williamsport and Altoona. Early in Socolow's tenure it was decided that additional mapping was needed to complete the northern parts of the bituminous coal fields. And in the late 1960's, mapping was begun in eastern Pennsylvania because

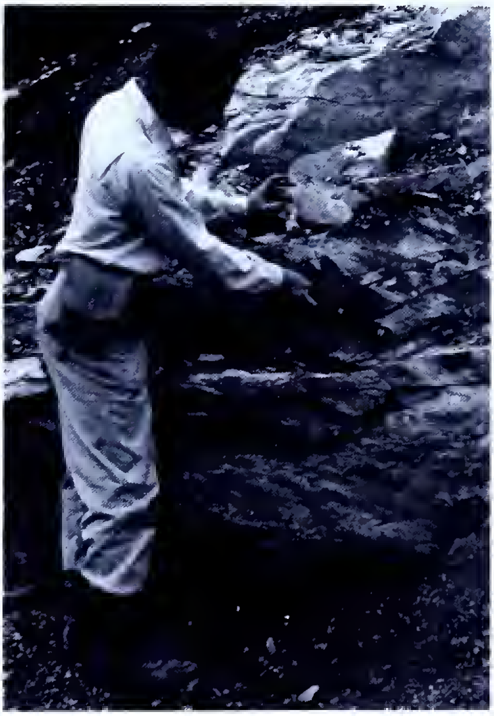


Figure 4. Vincent C. Shepps, geologist and editor for the Fourth Pennsylvania Geological Survey, measuring slickensides on a wrench-fault in Clearfield County during the summer of 1959. (Photo by A. R. Geyer).

of the expanding population growth there, and has been continued into the northeastern part of the state where virtually no work had been done since the Second Survey.

Figure 5. Arthur A. Socolow, fourth director and State Geologist of the Fourth Pennsylvania Geological Survey (1961-1986).

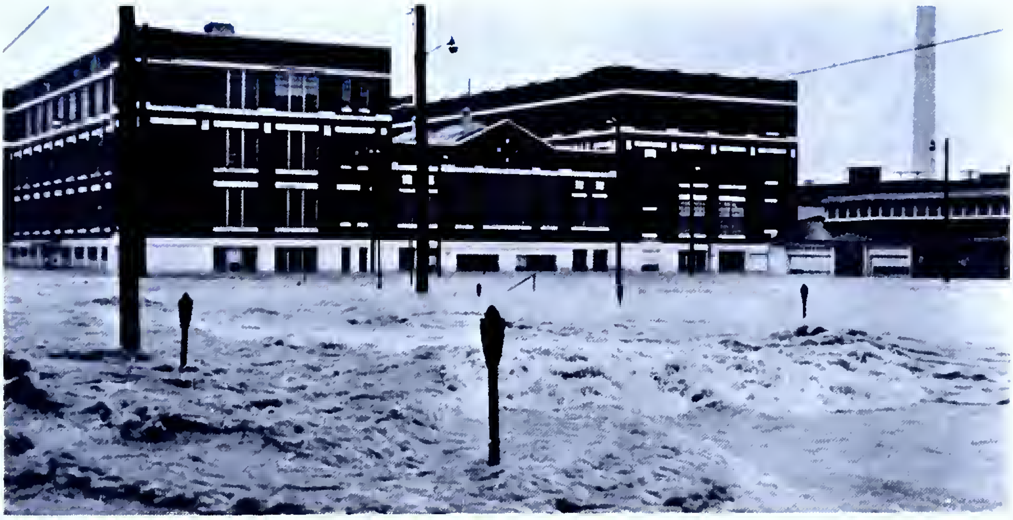
The Fourth Survey did not work in the Anthracite region in eastern Pennsylvania or in the southwestern part of the state, because of the large cooperative mapping program with the U.S. Geological Survey. In the late 1970's, a coal exploration model was developed by analyzing a small coal basin. Also at this time, the federal survey developed the National Coal Resource Data System (NCRDS), a computer-based program for storing detailed data on coals, from which coal quality and thickness maps could be generated. The Pennsylvania Survey's coal section has devoted its time and efforts since then to gathering and storing in this computer system the voluminous coal data from western Pennsylvania.

Perhaps one could say that 1972 was a watershed year for the Survey. For decades it occupied offices in Harrisburg, on the sixth floor of the South Office building. In March of 1966, the offices were moved to the Old Museum Building, but six years later expansion of the adjacent Governor's offices pushed the Survey out—into a building on an old flood plain of the Susquehanna River. No sooner had the Survey settled in when Agnes, the errant tropical hurricane, arrived in Pennsylvania, and stayed, and stayed, until the Survey's offices (and much else along the Susquehanna) were totally submerged. It took a while for the Survey to recover, but projects were soon underway again. Just as importantly, the generosity of many individuals went a long way in rebuilding the library, which had been totally destroyed.

Agnes, the errant tropical hurricane, arrived in Pennsylvania, and stayed, and stayed.

Figure 6. Offices of the Fourth Pennsylvania Geological Survey, underwater on June 23, 1972.

A just-completed study of the Reading Prong has provided invaluable data for evaluating the recently recognized radon hazard.



By the mid-1970's it was felt that sufficient modern mapping had been done that a revision of the 1960 Geologic map of Pennsylvania was in order. A number of the Survey's staff were engaged in this effort, which included a fair amount of reconnaissance work, utilizing air photographs extensively. After several years' effort, the map was published (Berg and others, 1980). Three years later, the first correlation chart for Pennsylvania was printed.

Mineral studies have been in the forefront of the Survey activities. In fact, one could argue that supplying geologic information for the extraction of the mineral resources is the ultimate justification for any Survey. Coal, and oil and gas, are the most valuable commodities in Pennsylvania, but numerous other minerals have been studied over the years, such as manganese and chromite. More recent studies have been done on zinc and lead deposits, copper and uranium, carbonate whiting, barite, and high-purity silica, among other mineral commodities. A just-completed study of the Reading Prong has provided invaluable data for evaluating the recently recognized radon hazard.

Much of the work by the Oil and Gas Division in the early Socolow years involved petroleum evaluations in various quadrangles of the western part of the state, in addition to an important stratigraphic study of the Lower Paleozoic formations in western and central Pennsylvania. Specific drilling target horizons, such as the Medina sandstone, were also evaluated. Late in the 1960's, a new series of maps was created, and periodically updated. This series includes every quadrangle in northern and western Pennsylvania that contains an oil or gas well, and shows the locations of these wells as well as the field/pool limits.

The need to examine and anticipate the effects of man's activities on our environment, and the geological factors involved has steadily increased over the years, and led to the creation of the Environmental Geology Division in 1968. The engineering properties of the various rocks of Pennsylvania was the first product of this new division. The Division has also engaged in water studies, the first of which was for the Susquehanna River Basin Commission. Other activities of the division have included studies on landside potential, sink hole development, and environmental geology of metropolitan areas.

In keeping with the desire to disseminate as widely as possible the geologic information the Survey generates, Socolow instituted three new publications series that have proved to be as popular as they are informative. *Pennsylvania Geology*, a bimonthly magazine begun in 1969, provides timely announcements and geologic descriptions for both professional and amateur geologists, and interested laymen. The Educational Series, begun in 1962, discusses in non-technical terms, broad aspects of geology, such as coal, the ice age, ground water, and geologic hazards. The Geologic Park Guides were begun in 1969 and now number 19. These guides describe in non-technical language the geology within and surrounding various state parks throughout the state.

Arthur A. Socolow retired in August of 1986, leaving a Survey with a staff of 43, which had accomplished a remarkable amount of work during his long tenure.

After serving as acting State Geologist for five months, Donald M. Hoskins was appointed the fifth State Geologist of The Fourth Survey on January 8, 1987.

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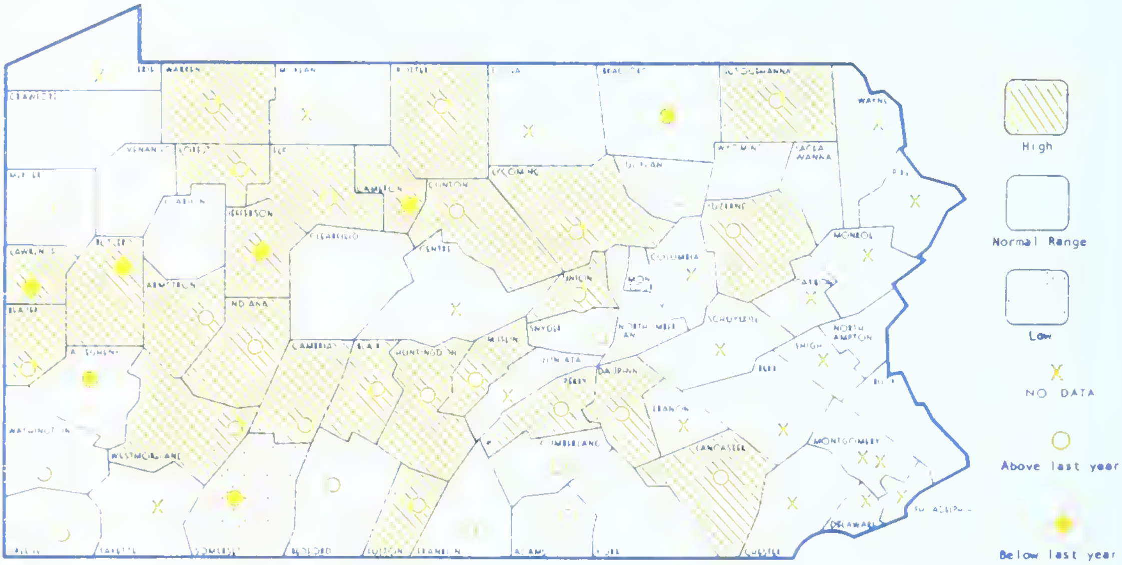

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ON THE COVER: Sinkhole in Macungie Borough, Lehigh County. The sinkhole opened on June 23, 1986, and was approximately 75 feet in diameter and 35 feet in depth. See article on page 11. (Photograph taken June 24, 1986, by W. E. Kochanov.)

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There Are No Magic Bullets

In the attempts we make in solving everyday geologic problems that arise from our interaction with our environment, we must continually remind ourselves that there are no easy answers, no "magic bullets," so to speak, to end these problems.

Two problems, having geologic origins, that face Pennsylvanians today are discussed in this issue. Both are the result of natural earth processes that have operated over eons, those grand divisions of geologic time that have transpired since the beginning of our planet.

The dissolution of our carbonate rocks to form sinkholes and the natural decay of uranium to form radon both have operated over very long periods of time. There is no way to stop such natural processes, no "magic bullet" to halt their progress.

Instead we must learn to understand these earth processes and adjust our activities to avoid their deleterious consequences. We need to know that we are part of our planet—our earth—our Commonwealth's environment—and by so knowing recognize and respect the natural processes. With appreciation of geologic time and the inexorable dynamic action of the earth's natural courses, we can better avoid problems that are part of our state's geology.

Donald M Hoskins

State Geologist

GEOLOGY IN THE PUBLIC ARENA

by Elisabeth Guerry Newton
Division of Geology and Mineral Resources
U.S. Bureau of Land Management

"Civilization exists by geological consent. . .subject to change without notice," according to Will Durant. It has been said that for every dollar that society is willing to invest in the application of the geosciences to the solution of its problems, the return to the public benefit is one hundred fold. It is within the public arena that this benefit is most evident.

Although our way of life has become more demanding upon our natural resources and our cultural and social environments have created population concentrations that cannot avoid geologically unsuitable habitats, it is positive to note that our decision makers and the public are becoming increasingly aware of the limits and constraints that natural conditions impose upon man's utilization of the earth's resources.

It is not so positive, however, to note that the requisite awareness of problems that are subject to solution through geological and engineering expertise often only occurs after a destructive episode, and is commonly accompanied by emotionalism and unrealistic interpretation of a worst ultimate outcome. Such was the case of the 1969 oil spill in the Santa Barbara Channel, California. There are equally frequent episodes, unfortunately, where, despite mounting evidence that a severe adverse situation is developing and life and property are being imperiled, a situation is ignored until tragedy occurs. This has been the case where floodplains have been developed, unstable terranes disturbed, water resources misused or mismanaged, or hazardous materials disposed of without proper regard for repository conditions.

Solutions and accommodations to issues such as these are usually addressed most effectively within the public sector. It is within this public arena that geology, and engineering geology in particular, can perform vital service by offering advice and counsel to a concerned public, and to policy and decision makers. It is essential that decisions affecting our natural resources, our health and welfare, and our national security be made with *proper consideration of,* and *respect for,* the relationship between such activities and natural geological conditions that must be accommodated.

Excerpt from the Keynote Address, "Symposium on Engineering Geology in Public Policy," Annual Meeting of the Geological Society of America, November 10, 1986, San Antonio, Texas.

Radon:
A Profound Case

by R. C. Smith, II, Pennsylvania Geological Survey
M. A. Reilly, Pennsylvania Bureau of Radiation Protection
A. W. Rose, The Pennsylvania State University
J. H. Barnes, Pennsylvania Geological Survey
S. W. Berkheiser, Jr., Pennsylvania Geological Survey

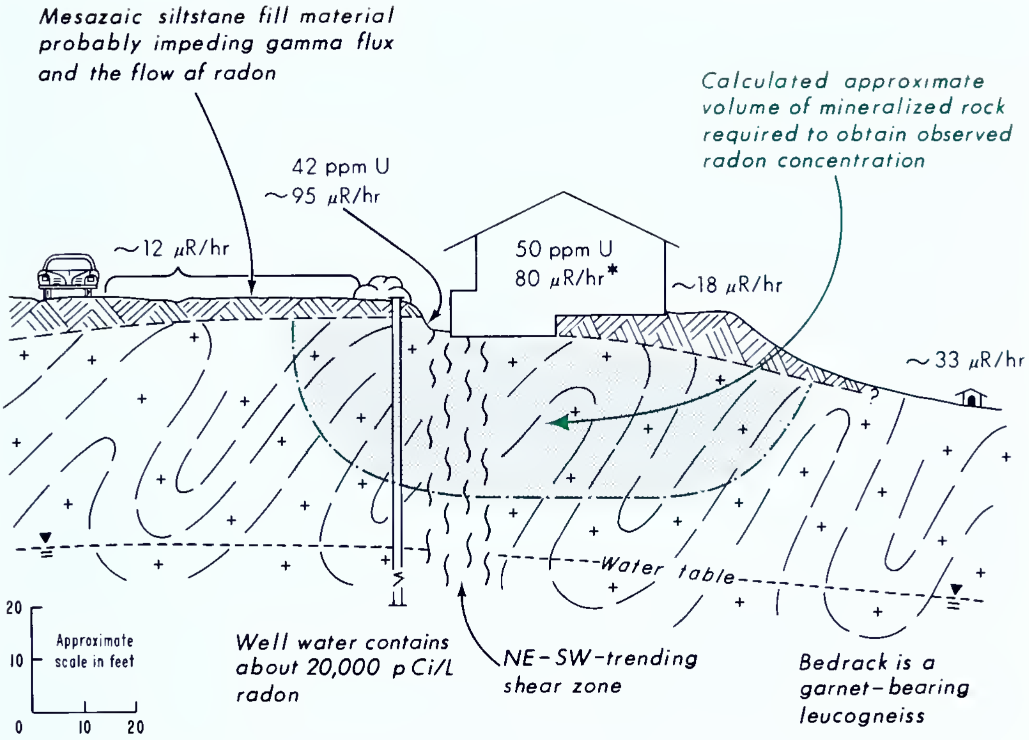
In late December 1984, the world's most severe indoor radon problem to date was discovered in a house in Colebrookdale Township, Berks County, in the Reading Prong physiographic province of Pennsylvania. Radon is a naturally occurring, colorless, odorless, inert, but radioactive gas, with a half-life of 3.8 days. It is a decay product of the most abundant naturally occurring isotope of uranium, U^{238}, and has radium as its immediate radioactive parent. Uranium and radon are found nearly everywhere in very small concentrations. Radon and its daughter products decay by the emission of alpha particles, essentially helium nuclei (two protons and two neutrons) carrying a charge of +2. Because of their large mass and charge, alpha particles travel only a short distance through body tissue, and have the capability of causing extensive damage when they encounter living tissue. The risk of lung cancer is understood to be proportional to the amount of exposure to radon decay products in air.

Radon is measured in radioactivity units called picocuries (pCi). One picocurie of radon is approximately the quantity that would yield the disintegration of two atoms per minute. The U. S. Environmental Protection Agency has suggested that the concentration of radon in the air of residential buildings should not exceed 4 picocuries of radon per liter (quart) of air. The house in Colebrookdale Township, the "Index House," was found to contain 2,500 pCi Rn/L (picocuries of radon per liter) for sustained periods.

How bad is that? Different individuals comprehend this in different ways. It is over 40 times the amount of radon allowed in active portions of U.S. uranium mines for a 40-hour work week. The annual radiation dose to the lungs continuously exposed to the Index House concentration is 8,700 Rem, or about 1 Rem per hour. For comparison, the worst exposure that could have theoretically been sustained by an individual during the March 1979 accident at the Three Mile Island nuclear power plant, had he stood on the edge of the property for the entire 11-day event, would have been only 83 milliRem, or 0.083 Rem (Battist and others, 1979). Thus, living in the Index House environment could be compared to being exposed to a TMI-like event 105,000 times each year! Living in the Index House could also be compared to having a chest X-ray every 20 seconds around the clock, or to smoking 136 packs of cigarettes per day, about one cigarette every 30 seconds. Using generally accepted risk models derived from a variety of independent sources, continuous exposure would result in a 13 percent lifetime chance of contracting lung cancer for each year of occupancy. Such comparisons serve to suggest the severity of the problem. Scientists and technicians can perhaps best comprehend the magnitude of the problem from the fact that air samples from the Index House yielded such high count rates that intrinsic germanium detectors could not keep pace, that opening the windows in the basement cut the gamma flux from 150 down to 60 μR/hr (microroentgens per hour) in that area (probably about 110 μR/hr cloud shine and 40 μR/hr flux through the floor and walls), or that visitors' clothing picked up a 70-μR/hr short-lived radon daughter contamination. Basement cracks yielded up to 250 pCi of radon per foot of crack per second!

What caused it? High indoor radon concentrations depend primarily on the amount of parent uranium in the bedrock and soil around a house, the efficiency with which the minerals involved emanate the radon that is produced, the porosity and permeability of bedrock and soil, house construction, life style (opening and closing of doors and windows), and especially "chimney effects." In the case of the Index House, several deleterious factors combined to yield a "worst case" situation.

A composite bedrock sample was collected from a 26-foot diagonal across the basement after the basement floor was removed (Figure 1). This sample yielded 50 ppm (parts per million) uranium (Table 1). If radiometric equilibrium existed, this would yield 17.5 pCi of radon per gram of rock. However, the average radon/uranium emanation efficiency is only about 20 percent (Table 1), and the rock actually releases only about 3.5 pCi/g (picocuries per gram). Calculations based on this and the fact that air in the Index House contained 1.6 mCi (millicuries) of radon, suggest that at least the first 30 feet of bedrock surrounding the basement was functioning as a radon source. However, a smaller volume of source rock is required if rock that has had less of its uranium leached is present at shallow depths. The mechanism whereby radon is concentrated from large volumes of rock into a house remains unclear. A water table no more than 47 feet below the surface suggests that upwelling groundwater may have been playing a deleterious role, even though the well water contains only about 20,000 pCi Rn/L, an amount exceeded by a factor of 12 elsewhere in the Reading Prong (Rumbaugh, 1983).


Mesozoic siltstone fill material probably impeding gamma flux and the flow of radon
42 ppm U
~95 μR/hr
~12 μR/hr
50 ppm U
80 μR/hr*
~18 μR/hr
Calculated approximate volume of mineralized rock required to obtain observed radon concentration
~33 μR/hr
Water table
20
10
0
Approximate scale in feet
10
20
Well water contains about 20,000 p Ci/L radon
NE-SW-trending shear zone
Bedrock is a garnet-bearing leucogneiss

* Median value of 64 measurements

Figure 1. Generalized cross section of the "Index House" site as viewed from the east, Colebrookdale Township, Berks County, Pennsylvania. The trench in front of the house was only temporary. The 80 μR/hr was measured in contact with bedrock beneath the lowest level of the house when it was fully ventilated. The width of the shear zone at this location is unknown.

Unlike the majority of the uranium occurrences in the Reading Prong, this occurrence is located in a faulted shear zone. It is probably similar to the one reported by Smith (1978) on the northwest side of Oley Valley, which was estimated to contain 58 ppm uranium. Neither area is particularly uranium-rich compared with other, anomalously radioactive Reading Prong "granitic" occurrences, which have a median uranium content of 81 ppm.

X-ray diffraction examination of the bedrock composite sample suggests that the source rock consists of major amounts of quartz, plagioclase, and a potash feldspar, and trace chlorite. Thin-section examination reveals that (1) the quartz, in particular, is highly sheared; (2) the feldspars are perthitic microcline and sericitized plagioclase; (3) fractured pink garnet is a minor component; (4) epidote occurs as radiating aggregates in fractures in the rock

Table 1. *Analyses of rock samples (in parts per million) from the Index House shear zone, Colebrookdale Township, Berks County. See Figure 1 for relative locations.*

	Uranium Fluorimetric (Commercial)	Uranium Delayed neutron activation (A. W. Rose)	Thorium Delayed neutron activation (A. W. Rose)	Percent emanation efficiency from radon/uranium (A. W. Rose)
Twenty-six-foot diagonal across basement floor*	50	49	33	12
Point source composite outside southeast foundation	42	44	47	14
Thirty-foot horizontal composite outside south foundation	28	30	47	12
Twenty-foot horizontal composite outside west foundation	36	35	58	36

*Commercial analyses of this deepest and freshest sample yielded 6.0 percent potassium, 55 ppm uranium, 81 ppm thorium, and 0.40 ppm europium. For comparison, the median contents of 47 widely separated "granitic" uranium occurrences in the Reading Prong are 81 ppm uranium and 161 ppm thorium.

matrix and with chlorite in garnet; (5) monazite occurs as subhedral grains with orange alteration (radiation damage?) rims; and (6) zircon is present as tiny euhedral, zoned grains. Fractions of increasing magnetic susceptibilities, prepared from a panned heavy-mineral concentrate, yielded minor amounts of ilmenite; abundant dark-orangish-red garnet; minor, partly altered tan monazite; and trace lustrous zircons with rounded terminations (many having brown cores and milky rims). Neither magnetite nor discrete uranium minerals were observed.

Semiquantitative trace-element analyses of the bedrock composite suggest a normal trace-element assemblage for a granitic rock, except for an observed lead content of about 100 ppm, which is high. The possibility exists that an appreciable fraction of the lead may be radiogenic. If 80 ppm of this lead is radiogenic and the occurrence formed near the end of the Grenville orogeny (approximately 1 billion years ago), then the unweathered rock could have contained on the order of 600 ppm uranium.

With research funding supplied by the Philadelphia Electric Company, ARIX Corporation supervised $32,670.81 worth of remedial construction and reduced the radon content of the Index House by a factor of over 1,000 and the gamma radiation levels from 28 to 13 μR/hr. The Index House is now safe. Obviously, had the risk from nature's radiation problem been identified and understood earlier, the house would not have been built as it was. Preconstruction caution in suspect terrain and private radon testing in the southeastern quarter of Pennsylvania are encouraged.

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NEW SURVEY PUBLICATIONS

THE NEW, REVISED STRATIGRAPHIC CORRELATION CHART OF PENNSYLVANIA

Pennsylvania Geological Survey General Geology Report 75 has been reprinted *and includes more than 80 revisions of varying degrees*. The **Stratigraphic Correlation Chart of Pennsylvania,** authored by T. M. Berg, M. K. McInerney, J. H. Way, and D. B. MacLachlan, has been one of the Survey's best sellers and has been used by a wide audience. When the chart was published in 1983, it was the first time that all of the stratigraphic names of groups, formations, members, and beds were ever assembled into one large diagram for the whole Commonwealth. The stratigraphic units of 15 geologically distinct areas in Pennsylvania are arranged in 15 vertical columns according to their age and vertical sequence as they occur in the field or in drill holes. The revisions to the chart, including the addition of some new names, occur mainly in the Quaternary, Lower Mississippian, Upper Devonian, Lower Silurian, and Lower and Middle Ordovician. Some revisions are simple corrections of misspellings in the original printing. Of special interest are the revision of the Middle Devonian (Tioga) and Ordovician ash-bed zones, and the addition of the Kalkberg, Belpre, and Center Hill ash-bed zones. The chart is available from the State Book Store, P. O. Box 1365, Harrisburg, PA 17105. The price is $5.40 (plus 32¢ tax for Pennsylvania residents). Enclose a check payable to *Commonwealth of Pennsylvania*.

NONFUEL-MINERAL PRODUCTION SHOWS INCREASE

The value of nonfuel-mineral production in Pennsylvania was $708.4 million in 1984, nearing the all-time high of $721.7 million in 1979. These and other facts about the production of nonfuel minerals in Pennsylvania are available free in Information Circular 95, **The Mineral Industry of Pennsylvania in 1984,** a newly released publication of the Pennsylvania Geological Survey. The report, written by L. J. Prosser, Jr., A. A. Socolow, and S. W. Berkheiser, Jr., is reprinted from *Minerals Yearbook 1984* by the U.S. Bureau of Mines. To obtain a copy of the publication, write to the Pennsylvania Geological Survey, Department of Environmental Resources, P. O. Box 2357, Harrisburg, PA 17120. Teachers interested in using the booklet in course work may order it in bulk quantity.

NEW OPEN-FILE REPORTS

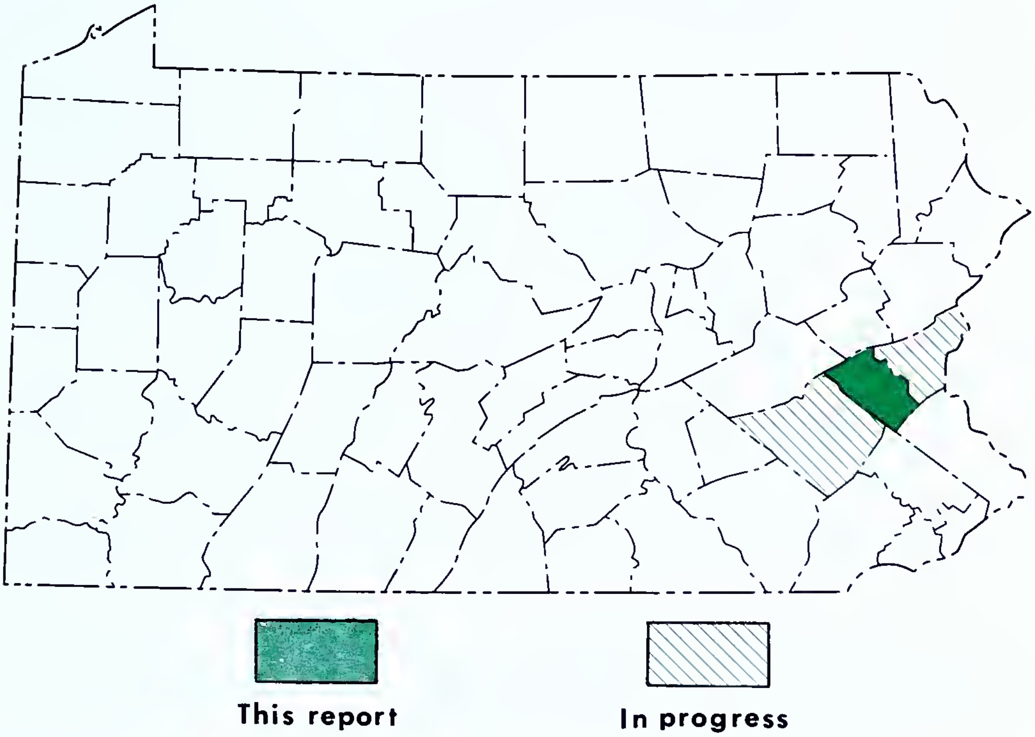
SINKHOLES IN LEHIGH COUNTY

The Pennsylvania Geological Survey has recently released Open-File Report 87–01, **Sinkholes and Related Karst Features of Lehigh County, Pennsylvania**. The report, compiled by staff geologist W. E. Kochanov, is the first in a series dealing with sinkhole occurrence and distribution throughout all of the limestone regions of Pennsylvania.

The report consists of six 7½-minute topographic quadrangle maps (scale 1:24,000) and a brief text. The maps depict known sinkhole occurrences, contacts of carbonate bedrock formations, structural data, past and present surface-mine locations, caves, and other karst-related features having surface expression. The text contains a brief discussion of the methods used in compiling the report, definitions of some basic terms pertaining to karst geology, and a list of references on the carbonate geology of Lehigh County.

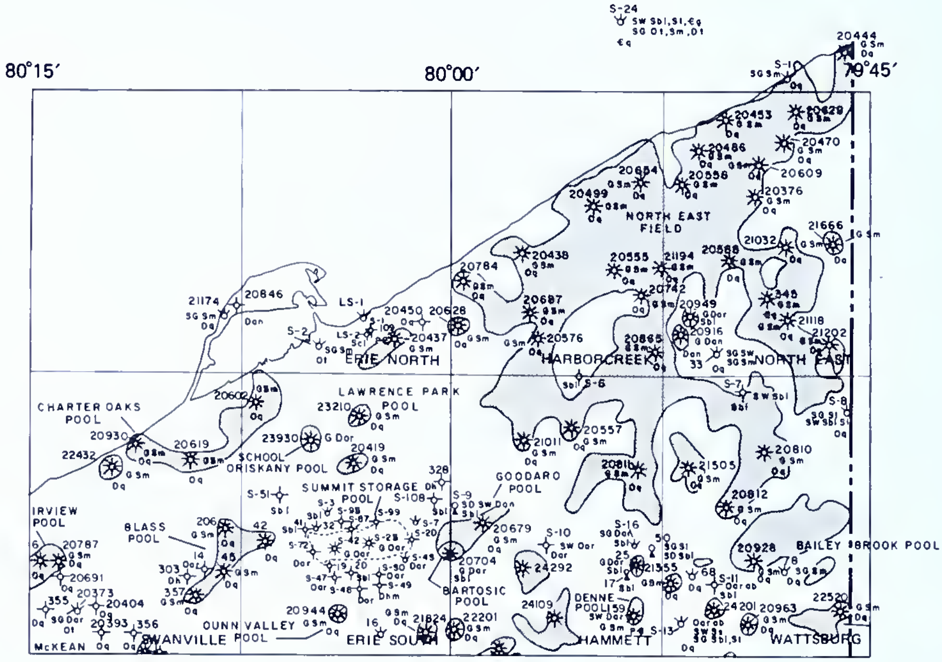
Concurrent with this report, a comprehensive computer data base concerning sinkholes in Pennsylvania is being developed at the Survey. Mapped sinkhole locations and physical data pertaining to specific sinkholes in Lehigh County have been entered into the data base by county, township, quadrangle (7½-minute), and coordinates (latitude and longitude). It will be continuously updated and utilized in answering requests for information on sinkholes in Lehigh County and eventually throughout the Commonwealth.

The Lehigh County open-file report can be examined at the offices of the Pennsylvania Geological Survey, 9th Floor, Executive House, 101 South Second Street, Harrisburg, or copies of the report can be purchased by mail order at the prepaid copying and shipping cost of $10.00 from the Pennsylvania Geological Survey, Department of Environmental Resources, P. O. Box 2357, Harrisburg, PA 17120. Checks should be made payable to *Commonwealth of Pennsylvania*.



REVISED MAP OF DEEP WELLS AVAILABLE

A revised and updated version of **Deep Well Oil and Gas Exploration and Development in Pennsylvania,** Open-File Report 2 of the Pennsylvania Geological Survey, has been completed and is now available as an ozalid (blueline or blackline) print to interested parties. The report, which was last updated in 1982, consists of a map in two sheets at a scale of 1:250,000, compiled and drafted by L. J. Balogh. The map shows the locations of several thousand deep wells (wells that penetrate the top of the Middle Devonian Tully Limestone or its equivalent) in Pennsylvania. All deep wells outside established fields are shown. Only selected wells within developed areas are shown, however, because of space limitations at this scale. All wells are identified by permit number (or Survey file number for wells drilled before permitting), and information is provided regarding formation at total depth, shows of oil, gas, and water, and producing formations. There is a new feature on this revision: the fields and pools, many of which are named on the map, are highlighted with a stipple pattern that makes it far easier to distinguish developed areas from potential exploratory areas (see the example printed below).



Details for ordering Open-File Report 2 can be obtained by contacting the Pennsylvania Geological Survey, Oil and Gas Geology Division, 7th Floor, Highland Building, 121 South Highland Avenue, Pittsburgh, PA 15206-3988, telephone 412-645-7057.

AERIAL PHOTOGRAPHS PROVE SINKHOLE ORIGIN

by William E. Kochanov
Pennsylvania Geological Survey

On June 23, 1986, a large sinkhole opened suddenly in Macungie Borough, Lehigh County (Figure 1). The sinkhole, which measured approximately 75 feet in diameter and 35 feet in depth, occurred in a street separating an apartment and a townhouse complex (Figure 2). Continued sloughing of the sides of the sinkhole and radiating tension cracks, which encroached on an adjoining parking lot, prompted the evacuation of 20 homes and apartments. Fortunately, there were no injuries to residents as a result of the collapse, but damage to the street and buried utility lines was extensive.

The Pennsylvania Geological Survey became involved with the Macungie sinkhole through a request to the Department of Environmental Resources from the borough manager. The Environmental Geology Division of the Survey worked in a cooperative effort with borough officials, consultants, and building contractors by supplying background information on the carbonate geology of the area and investigating the recent history of the site in order to determine an effective and feasible solution to the problem.

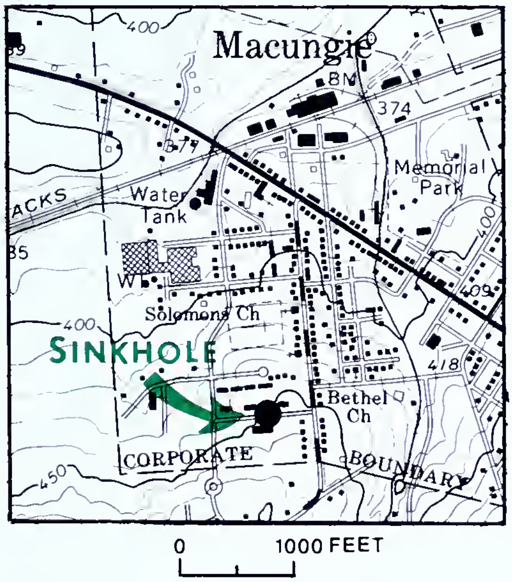


Figure 1. Sinkhole location in the Allentown West 7½-minute quadrangle.

The collapse occurred in colluvial and recent fill materials overlying the Middle Cambrian Leithsville Formation. The Leithsville is a dark-gray to medium-gray, massive dolomite containing thin calcareous shale and sandy dolomite interbeds. The surficial colluvial materials in the area of the sinkhole consist largely of granitic gneiss and quartzitic sandstone fragments, derived from the hills to the south, in a residual soil matrix.

The history behind this occurrence is interesting and well documented by a sequence of aerial photographs.

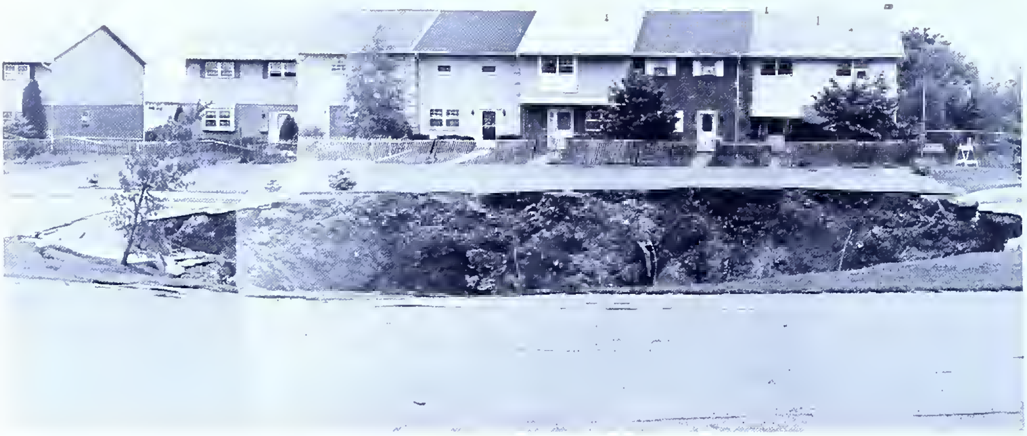
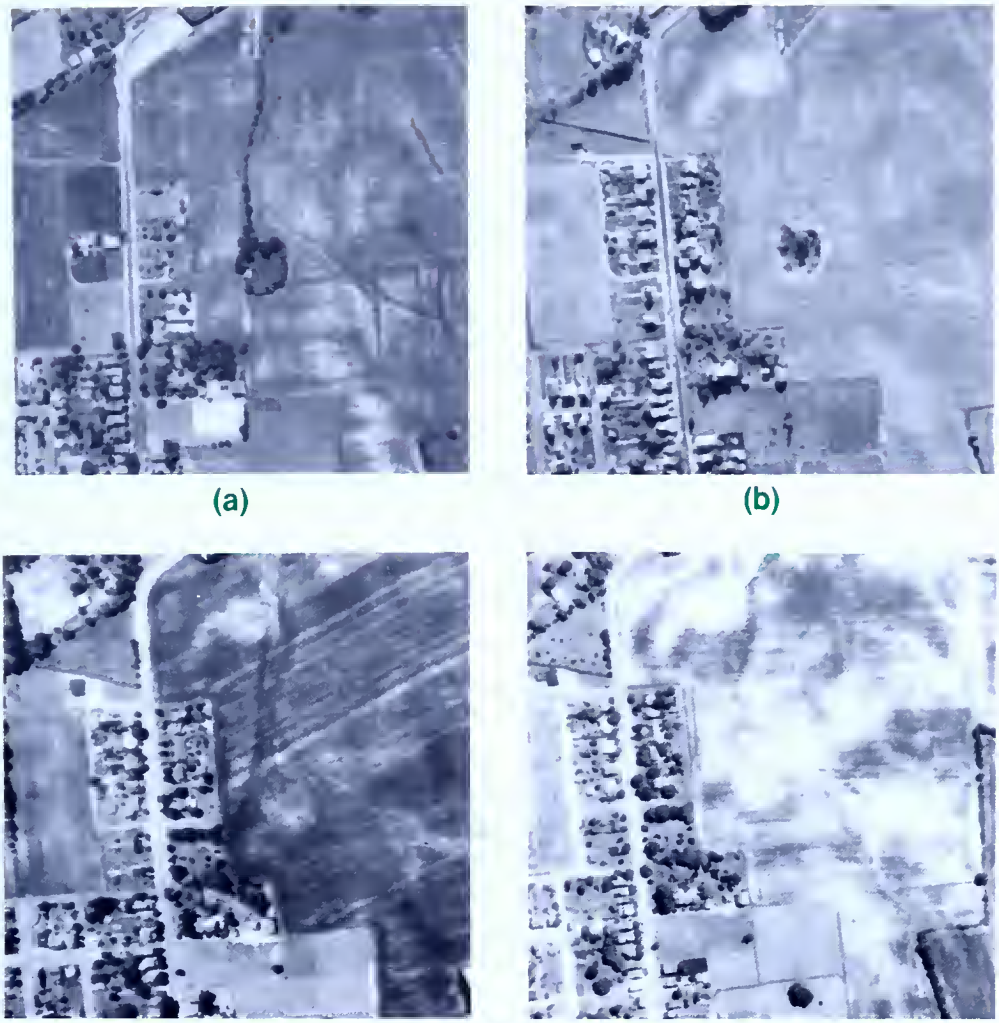


Figure 2. Sinkhole in Macungie Borough as it appeared on June 24, 1986.

Interviews with longtime residents of the area revealed that a pond had existed in approximately the same location as the sinkhole. It was also suggested that the sinkhole could have been a reopening of a previously existing iron mine. Information on past mining operations obtained from the Mineral Resources Division of the Pennsylvania Geological Survey and from the U.S. Bureau of Mines showed that no mining had taken place in the area of the collapse.

To determine the origin of the collapse, aerial photographs were used as an aid in establishing the history of the site. The Pennsylvania Geological Survey library has sequential aerial photographic coverage of the entire state for the past 40 years. Examination of the site of the Macungie sinkhole on a 1947 aerial photograph (Figure 3a) shows a roughly circular water-filled pond approximately 200 feet in diameter. Examination of a photograph taken in 1958 (Figure 3b) shows a deep hole that no longer contained any water. At the northern end of the hole, several dark circles are apparent, and from this it was deduced that there was at least one, and perhaps three, openings that drained the pond sometime between 1947 and 1958. Further photographic evidence from 1964 and 1971 shows that the hole had been filled and crops planted over it (Figure 3c and 3d). A stereo zoom transfer scope, which allows one to view a pair of stereo air photographs and to transpose that image onto a base map, was used to verify that the "pond" and the recent sinkhole were indeed at the same location.

Repair of the sinkhole occurred over a period of more than 3 months and cost the borough over $400,000.



(a)

(b)

(c)

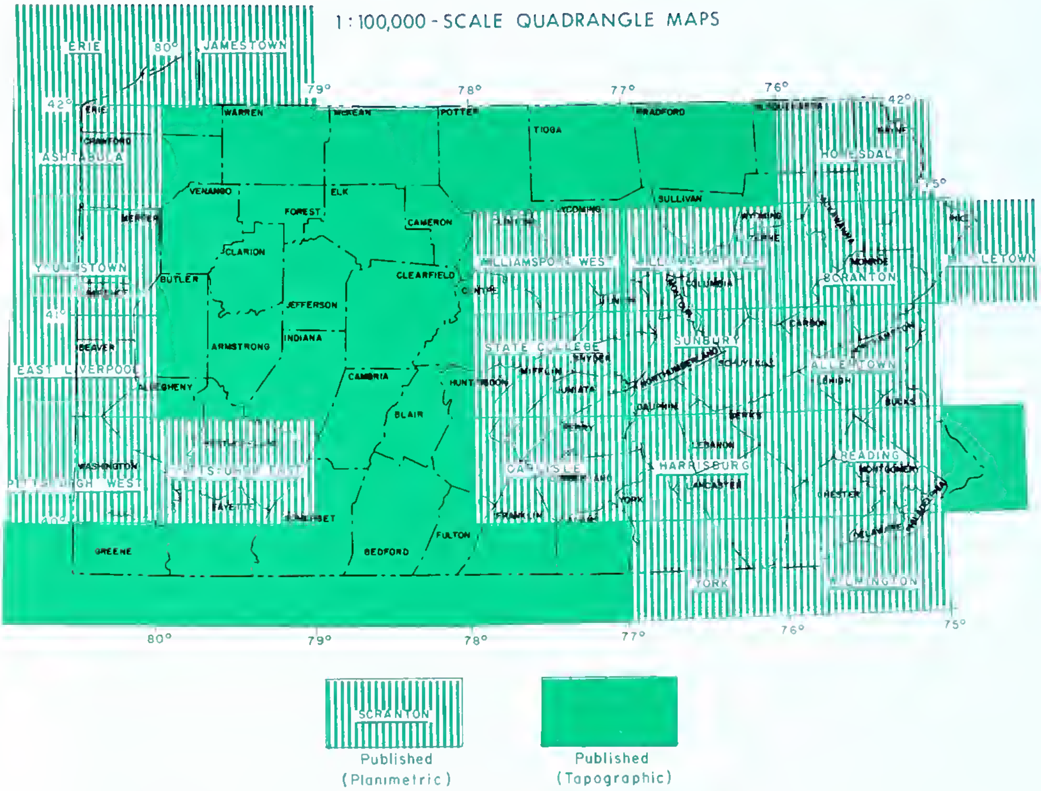
(d)

Figure 3. Sequence of aerial photographs showing the evolution of the Macungie sinkhole: (a) 1947, (b) 1958, (c) 1964, and (d) 1971. All photographs are from the U.S. Department of Agriculture. Development in the area occurred after 1971.

This account dramatically illustrates the need for an evaluation of foundation conditions in carbonate bedrock areas. The severe damage caused by sinkholes can be minimized by incorporating a thorough subsurface investigation in the planning stages of a project in an area that is considered to be prone to sinkhole development. In the case of Macungie Borough, it would have been to the benefit of the developers of the area or their engineers to have examined the various series of aerial photographs, available to the public, prior to the onset of any construction activity.

U.S. GEOLOGICAL SURVEY METRIC TOPOGRAPHIC MAPS

In April 1984, a series of topographic maps at a scale of 1:100,000 (1 centimeter on the map equals 1 kilometer, or about 1.6 miles, on the ground), was announced in *Pennsylvania Geology*. The maps are multicolored, and show political boundaries, highways, man-made structures, cultural features, and topographic contours (interval 20 meters). In addition to providing much of the detail shown on larger maps, the 1:100,000-scale maps cover enough geographic area to be useful as regional base maps.


1:100,000-SCALE QUADRANGLE MAPS

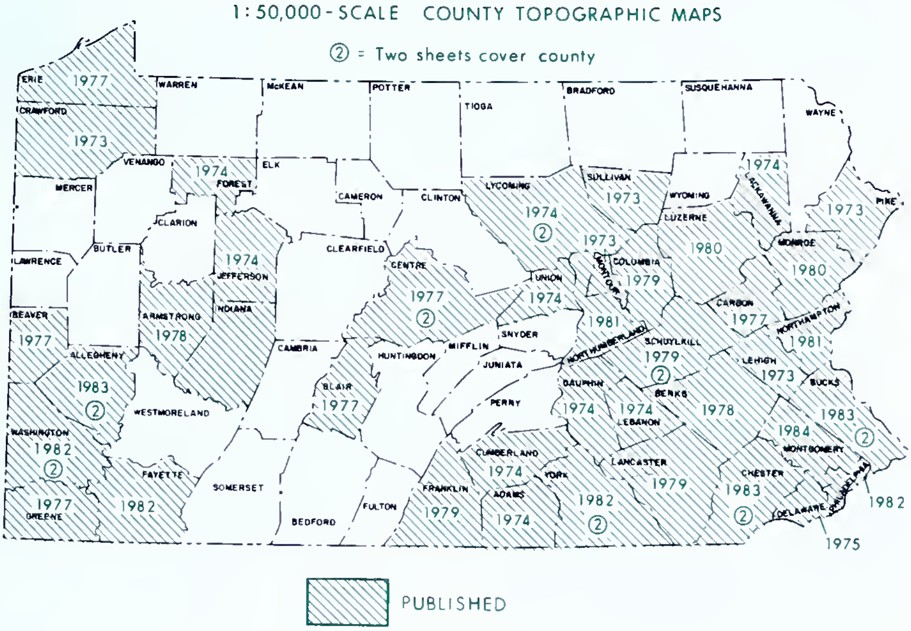
Thirty-four maps in this series have been completed for Pennsylvania. Fourteen of the maps are in a topographic format and 20 in a planimetric format. Eventually all of the maps in this series will depict topography. Please refer to the index map for coverage information.

Published maps are available for $4.00 each from the U.S. Geological Survey, Map Distribution, Box 25286, Federal Center, Denver, CO 80225. Prepayment is required, and checks should be made payable to *U.S.G.S.* For more information, contact the Pennsylvania Geological Survey library (NCIC Affiliate) at 717-783-8077, or NCIC-Mid Continent, U.S. Geological Survey, 1400 Independence Road, Rolla, MO 65401 at 314-341-0851.

COUNTY TOPOGRAPHIC MAPS

During 1986, the Pennsylvania Geological Survey and the Topographic Division of the U.S. Geological Survey continued their cooperative program to prepare and maintain topographic maps for Pennsylvania.

One series of topographic maps prepared as part of the program is the 1:50,000-scale county map. This series of maps shows (1) landforms through the use of contour lines; (2) surface features, including rivers, streams, and lakes; (3) man-made features, including woods, trails, railroads, and major buildings; and (4) political boundaries, including township, borough, and city lines. The multicolored maps have contours (inverval 20 feet) printed in brown, man-made features in black, major roads in red, urban areas in pink, forested areas in green, water features in blue, and political boundaries in orange.


1:50,000-SCALE COUNTY TOPOGRAPHIC MAPS

② = Two sheets cover county

The 1:50,000 maps are available for 39 counties, as shown on the index map on the preceding page.

The maps can be obtained for $4.00 each ($8.00 for Allegheny, Bucks, Centre, Lycoming, Schuylkill, Washington, and York) by writing to the U.S. Geological Survey, Map Distribution, Box 25286, Federal Center, Denver, CO 80225. Prepayment is required, and checks should be made payable to *U.S.G.S.* Lehigh County (Pennsylvania Geological Survey Map 39) is available from the State Book Store, P. O. Box 1365, Harrisburg, PA 17105. The price is $1.65 (plus 10¢ tax for Pennsylvania residents); enclose a check payable to *Commonwealth of Pennsylvania.*

For more information, contact the Pennsylvania Geological Survey library (NCIC Affiliate) at 717-783-8077, or NCIC-Mid Continent, U.S. Geological Survey, 1400 Independence Road, Rolla, MO 65401 at 314-341-0851.

New Staff of the Pennsylvania Geological Survey

Sherry G. Datres

Sherry G. Datres, who originally hails from the Bluegrass State of Kentucky, joined the Survey in April 1986 as a Clerk Typist in the Editing Section.

Prior to joining the Survey, Sherry worked for a private geologic consulting firm, where she gained extensive knowledge relating to the geologic makeup of Pennsylvania and adjacent states. Before learning about geology and groundwater, Sherry spent her time working for the U.S. Army Security Agency gathering intelligence data.

Francis W. Nanna

Frank Nanna, from Johnstown, Pennsylvania, joined the Survey in June 1986. Frank graduated from Slippery Rock University with a B.S. in recreation in 1977. After graduation he was employed by engineering firms in Texas and Pennsylvania. Frank works in the Editing Section as a Cartographic Draftsman.

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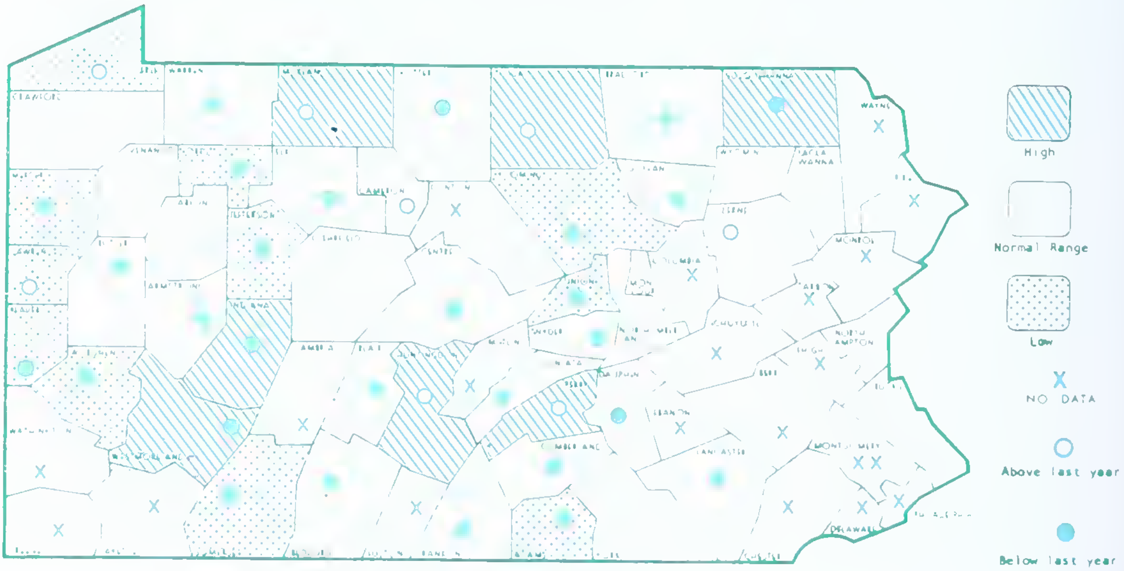
GROUNDWATER RESOURCE MAPPING

GROUNDWATER LEVELS
FOR
MARCH 1987



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ON THE COVER: The Susquehanna River Overlook, along the Appalachian Trail on Peters Mountain, Duncannon 7½-minute quadrangle, Dauphin County. The overlook affords an outstanding view to the north of the Susquehanna River valley (foreground) and the Juniata River valley (background). The site is one of many included in the new Survey publication *Outstanding Scenic Geological Features of Pennsylvania* (see article on page 6). Photograph by J. P. Wilshusen.

PENNSYLVANIA GEOLOGY is published bimonthly by the Bureau of Topographic and Geologic Survey, Pennsylvania Department of Environmental Resources, Harrisburg, Pennsylvania 17120.

Editor, Christine M. Dodge

Articles may be reprinted from this magazine if credit is given to the Topographic and Geologic Survey.

VOL. 18, NO. 3 **JUNE 1987**

From Lakes to Seas—The Beauty and Wealth of Our Commonwealth

Some years past a bus line traversed our Commonwealth, the Edwards Lakes to Seas Bus Company, which traveled from Cleveland to Pittsburgh, thence to Williamsport via Clearfield, and finally to Philadelphia, crossing Pennsylvania's Anthracite region. This was an unusual route, not the direct routes of today's rapid transit, but indirect and winding. The advantage to the traveler of this circuitous route was that a varied and large amount of our Commonwealth's scenery was able to be viewed.

In a recent publication of our Bureau (described in this issue), we provide more information on Pennsylvania's scenic features, some of which may have been seen by a bus sojourner who traveled from northwestern Pennsylvania to the tidal waters of Philadelphia. Along this route near Homewood is Homewood Falls, an example of many scenic falls of western Pennsylvania. In Clarion County at Alum Rock is an overlook on the Clarion River, reputedly one of the best places to view our western plateau topography. Side trips from the bus route would have led you to many of the famous springs of central Pennsylvania, such as Big Spring, Blue Spring, and Beaver Spring in Centre and Clinton Counties, which produce copious quantities of our most valuable resource—water. Further east near Jim Thorpe are Onoko and Chameleon Falls in the Lehigh River Gorge State Park—a delight for hikers. Near tidewater is Devils Pool in Philadelphia.

All of these sites are described with photographs and maps in Part 2 of *Outstanding Scenic Geological Features of Pennsylvania*. To the 389 sites described in Part 1 are added the 125 newly described sites of Part 2. A sojourner's trip along the old Lakes to Seas route accompanied by Parts 1 and 2 of this report will show you the true beauty of our Commonwealth.

Should you arrive at Erie, lake port of our Great Lake, perhaps you can get a glimpse of the dredge ship which sails from Erie and produces valuable mineral resources as described in this issue's mineral resources contribution.

Donald M Hoskins

State Geologist

ERIE SAND AND GRAVEL COMPANY
Suction Hopper Dredging on Lake Erie

by Samuel W. Berkheiser, Jr.
Pennsylvania Geological Survey

Erie Sand and Gravel Company, Erie, Pennsylvania, has been providing valuable fine aggregates to northwestern Pennsylvania for nearly a century. In 1888, wheelbarrows, shovels, and perspiration supplied aggregate mined from the peninsula, Presque Isle, to the local market. This quickly led to hydraulic dredging around the harbor area by small, 100-ton boats. Company records contain dredging permits dating back to 1910. Today, about 1,100 cubic yards of quality (Type A) fine aggregate is dredged from Lake Erie about 8 to 15 miles northwest of Presque Isle in two shifts per day. At the end of the company's pier is moored the dredge *Niagara* (not to be confused with Admiral Perry's flagship *Niagara*), which was commissioned in 1897 and is reported to be the oldest vessel under certification by the U.S. Coast Guard.

GEOLOGY. Lake Erie, straddling Pennsylvania's international border with Canada, is the shallowest of the Great Lakes. Three ridges cross the lake bottom in a general northwest-southeast trend, one between Lorain, Ohio, and Pelee Point, Ontario, another between Cleveland, Ohio, and Erieau, Ontario, and a third between Erie, Pennsylvania, and Long Point, Ontario. These late Pleistocene end moraines formed during glacial advances into the Erie basin (Pope and Gorecki, 1982). The Erie-Long Point moraine is generally composed of clay-sized till overlain by sand and/or gravel and is an important economic resource for Pennsylvania. Lewis (1966) attributed it to the Port Huron advance, 12,900 years B.P. (before present), which raised the lake to a level about 160 feet higher than the present level, forming Lake Whittlesey. The overlying sand and gravel of the moraine is believed to be a lag deposit formed when the ice retreated to the point that water could drain through the Niagara River, resulting in the formation of Early Lake Erie (12,370 to 12,790 years B.P.), about 100 feet lower than the present level (Lewis, 1966; Lewis and others, 1966). This sand and gravel averages about 7.5 feet in thickness (Pope and Gorecki, 1982) and may contain between one-half billion and 1 billion tons of valuable resource. In contrast, most of the commercial land-based sand and gravel deposits in northwestern Pennsylvania are much smaller and contain older (20,000 years B.P.) glacial material related to the Kent advance. A natural trench or breach in the Erie-Long Point moraine about 4 miles offshore physically separates it from the changing and dynamic Presque Isle Peninsula.

MINING. Erie Sand and Gravel Company operates the *J. S. St. John,* a suction hopper (sand sucker or hydraulic) dredge out of Erie Harbor. Commissioned as a U.S. Navy tanker in 1949, it was converted during the 1960's to a dredge. Maximum dredging capacity per shift is about 550 cubic yards, or 750 tons, which requires about 4 to 6 hours of pumping time to collect. Approximately 200,000 tons of sand is mined annually.

The dredging machinery itself is rather simple in concept (Figure 1). A 16-inch-diameter pump powered by a 200-horsepower diesel engine sucks material from the lake bottom end moraine through a hood that limits the maximum size of the material to about 3 inches in diameter. The pumpman's duty is to regulate a smooth flow of the material that is less than 3 inches in diameter over the screening trough by adjusting the vacuum (which regulates the water content) and the height of the hood above the substrate. Sand passes through the screens in the trough and exits into the hold of the ship through adjustable gates located below each screen. The deckhand regulates the flow of sand over the screens and into the hold by adjusting the four gates on each of the eight identical screens. Oversized material is returned to the lake. The captain, through his expert eye and past

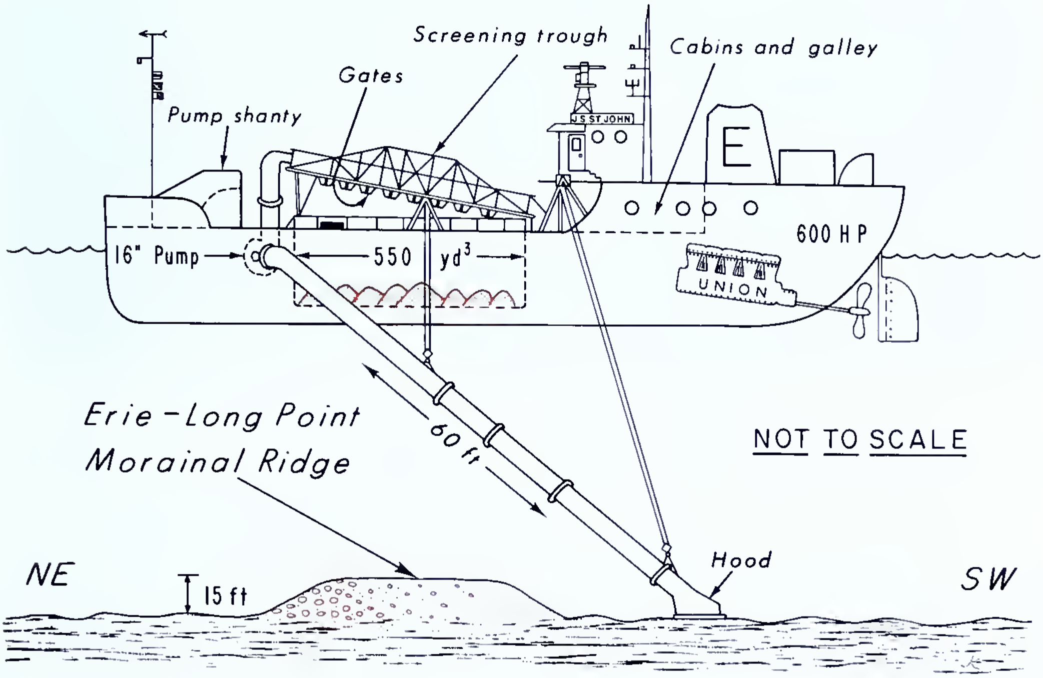

Figure 1. Sketch of the *J. S. St. John* showing essential equipment of a suction hopper dredge.

experience, finely tunes the whole system by monitoring the size of the material coming out of the gates (Figure 2) and making adjustments to speed and course. The captain's skill in knowing where the correct size of material can be found within the permit area is essential for efficient operation. A typical pass, when first initiating a dredging run, is an oval circuit about 1 mile long and one-fourth mile wide. Once production is steadied, the ship may sustain a consistent flow of sand by turning to port (left) in circles of small diameter. The ship's engineer is responsible for keeping the diesel engines running and serviced (every hour), and for adjusting ballast as required in the hold and in four main tanks located along the ship's longitudinal axis.

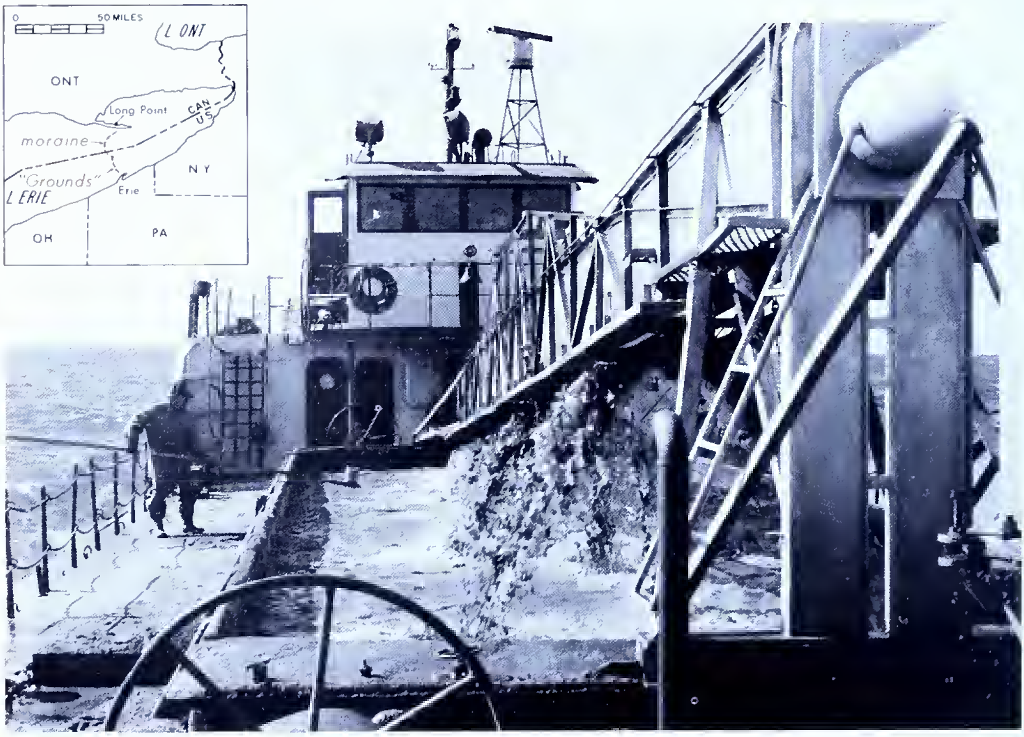

Figure 2. Captain Ostroski sampling dredged sand as it exits the gates below the screening trough. Insert shows a generalized location map of the region.

The mining season generally extends from May through November. Twenty-foot seas are not uncommon on Lake Erie; the *St. John* will not usually go out in seas greater than 6 feet. The *St. John* has a maximum speed of about 8 knots (10 miles per hour), and it generally takes about 5 miles to reach this speed when fully loaded.

The U.S. Army Corps of Engineers, the Bureau of Dams and Waterway Management within the Pennsylvania Department of Environmental Resources, and the Pennsylvania Fish Commission regulate the commercial exploitation of this resource. The "Erie Grounds," or permit area, trends west-northwest to south-southeast and is an irregular zone about 6 miles long and about 2 miles wide, starting at a point about 8 miles northwest of Presque Isle. The *St. John* is equipped with radar and Loran C navigation devices which give reasonable location accuracy (±50 feet). The captain is required to log in his position in Loran C or radar coordinates every half hour, and there is little chance of straying outside the permit area. The Fish Commission collects a royalty of 10 cents per ton or 15 cents per cubic yard.

MARKETING. Upon returning to port, the screening trough on the *St. John* is pushed aside and the 3-hour-long process of off-loading sand by crane and clamshell-bucket to stockpiles begins. The crane operator is responsible for assuring a proper blend of material in the stockpiles, depending on the final end-use.

About 40 percent of the product mined from Lake Erie is sold as PennDOT-approved, Type A concrete sand. "Block grit," used for the manufacture of concrete building blocks, mason sand, used as mortar mixes, and "snuff sand," used as a mineral filler by GAF Corporation, round out the product line for the dredged material. The material dredged 8 to 15 miles offshore is in no way affecting the dynamic processes that are causing Presque Isle beaches to migrate eastward. In fact, sand and gravel from the Erie-Long Point moraine should work well in beach replenishment projects because of the very low clay content and natural gradation. Through other corporate endeavors, Erie Sand and Gravel Company also transports and markets annually about 200,000 tons of limestone from the same pier. This includes fine and coarse aggregate shipped in its own vessels from Marblehead, Ohio, and Drumond, Michigan.

Thanks is extended to the day crew of the *J. S. St. John*, Captain John Ostroski, Chief Engineer Richard Dudek, Pumpman William Straub, and Deckhand Glen Weist, for their cooperation and patience in gathering data for this article. Thanks is also given to Sidney E. Smith, Jr., President, and Sandy E. Smith III, Marketing Manager, of Erie Sand and Gravel Company for their time and cooperation in preparing this article.

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NEW SURVEY PUBLICATION

OUTSTANDING SCENIC GEOLOGICAL FEATURES OF PENNSYLVANIA

PART 2

A second volume of *Outstanding Scenic Geological Features of Pennsylvania* has been released. It is Pennsylvania Geological Survey Environmental Geology Report 7, Part 2, 1987. Written by Alan R. Geyer and William H. Bolles, both of whom authored the first volume, this new publication contains the location and a brief description of 125 additional sites throughout the state. Parts 1 and 2 together of *Outstanding Scenic Geological Features of Pennsylvania* now provide a comprehensive listing and description of 514 of the best known geological sites, arranged by physiographic province.

Also included are two appendices of named springs and waterfalls in the state. In addition to location, yield and data source are given for springs and the height is given for waterfalls.

Both of these publications are available from the State Book Store, P. O. Box 1365, Harrisburg, PA 17105. The price of EG 7, Part 1 is $6.05 (plus 36¢ tax for Pennsylvania residents), and the price of EG 7, Part 2 is $3.95 (plus 24¢ tax for Pennsylvania residents).

◄ Indian Chief Rock, Blair County, one of many sites described in Environmental Geology Report 7, Part 2.

THE GEOGRAPHIC NAMES INFORMATION SYSTEM

The Geographic Names Information System (GNIS) is an automated data system, comprising five separate data bases, that has been developed by the U.S. Geological Survey to compile, standardize, and disseminate information on geographic names in the United States and its territories. All known places, features, and geographic areas that have been identified by a proper name are included in GNIS.

The primary data base in GNIS, called the National Geographic Names Data Base, contains more than 2 million names of places and features in the United States. The information is filed by state, and the compilation of data for each state is divided into two phases. During Phase I, all geographic names from U.S. Geological Survey topographic maps are entered into the system. In Phase II, historical and variant geographic names as well as names and features from sources other than U.S. Geological Survey topographic maps are added. After both phases have been completed for a state, the results are published as a separate volume of Professional Paper 1200, *The National Gazetteer of the United States of America*. Presently, state volumes are available for New Jersey, Delaware, and Kansas; the remaining states are scheduled for completion in the next 8 years.

Phase I data are currently available for Pennsylvania as bound computer lists priced at $34.00 or as magnetic tape priced at $50.00. An example of the descriptive elements contained in the computer listing for each geographic name is shown below. Special searches of the system for specific descriptive elements may be requested, and the results are available as computer printouts or magnetic tapes.

The data base may be accessed in the regional information offices of the National Mapping Division of the U.S. Geological Survey. For further information, contact GNIS Manager, 523 National Center, Reston, VA 22092 (telephone 703-860-626).

```
ID NUMBER -  42020727
NAME - Presque Isle
BGN DECISION - 1900
TYPE OF FEATURE -  island
STATE/COUNTY FIPS CODE - 42049
GNIS MAP NO -  0001 0006
GEOGRAPHIC COORDINATES - 420947N0800605W 420713N0800901W
USGS QUANDRANGLE CODE - 42080-B1
VARIANT NAME(S) -  Presqu'Ile, Presque Isle Peninsula
COUNTY NAME - Erie
FEDERAL STATUS - BGN
MAP OR CHART NAME - Swanville, Erie North
```

Example of printout showing Phase I data for a geographic feature in Pennsylvania.

"JAWS" IN PENNSYLVANIA:

Physonemus and Other Vertebrate Fossils from the Vanport Limestone of Lawrence County, Pennsylvania

by William Marks, Pennsylvania Department of Environmental Resources, Ebensburg, Pa., and
Maryjo Peluso-Marks, Consulting Geologist, Loretto, Pa.

The Middle Pennsylvanian Vanport Limestone is widely exposed in quarries, highway and railroad cuts, and stream gullies throughout Lawrence County. Many of these outcrops contain a rich and varied marine fauna, including brachiopods, gastropods, bryozoans, cephalopods, corals, and crinoids. Where the limestone layers have been open to the atmosphere for a number of years, countless invertebrate fossils retaining great detail can be found weathered out of the rock matrix.

Much rarer, however, are the vertebrate fossils noted at three localities in the central part of the county (Figure 1). These fossils consist of detached teeth and spines of extinct sharklike creatures (Class Chondrichthyes) that prowled the Vanport sea in search of prey to satisfy their ravenous appetites.

Teeth of the ancient shark *Petalodus* (pictured in Lesley, 1890) were found at all three outcrops. When reconstructed, these teeth are triangular in shape, approximately 2.5 cm in length and width, and convex on one side and concave on the other (Figures 2 and 3). Specimens are clearly visible in the matrix because of their

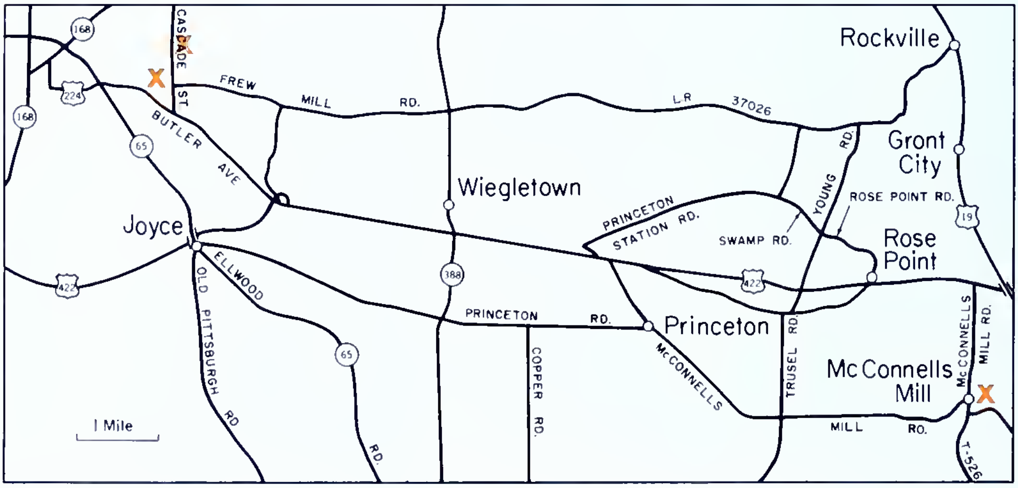

Figure 1. Location map. Collecting localities are marked by X's.

characteristic "robin's egg" blue color. *Petalodus* was apparently a pavement-toothed shark of the ?Order Bradyodonti (Romer, 1966).

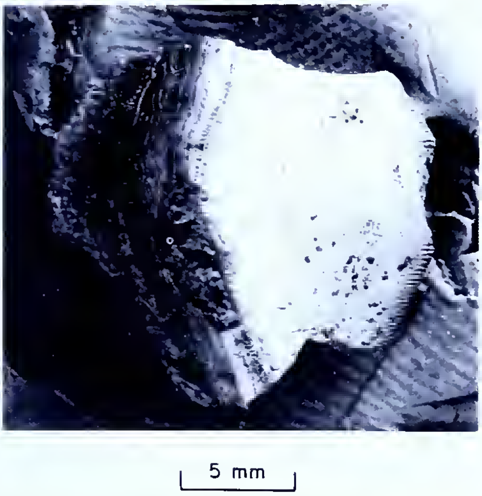

Figure 2. ***Petalodus,*** **convex side of tooth, McConnells Mills.**

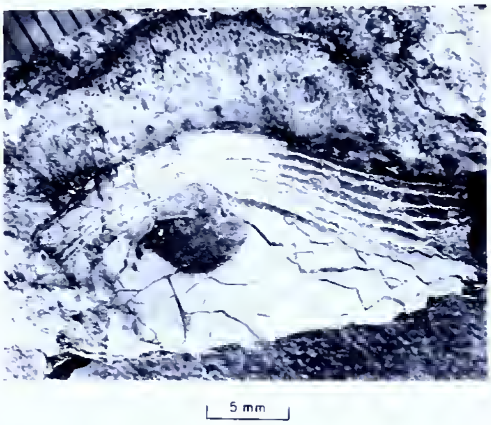

Figure 3. ***Petalodus,*** **concave side of tooth, McConnells Mills.**

Several teeth of another type of shark were also found at the same localities. The teeth have a lobe shape and are approximately 2.5 cm in width. One side is minutely porous (Figure 4), and the other exhibits a network of canals. The collected specimens fit the description of the teeth of *Deltodus,* an ancestor of the modern Chimaera

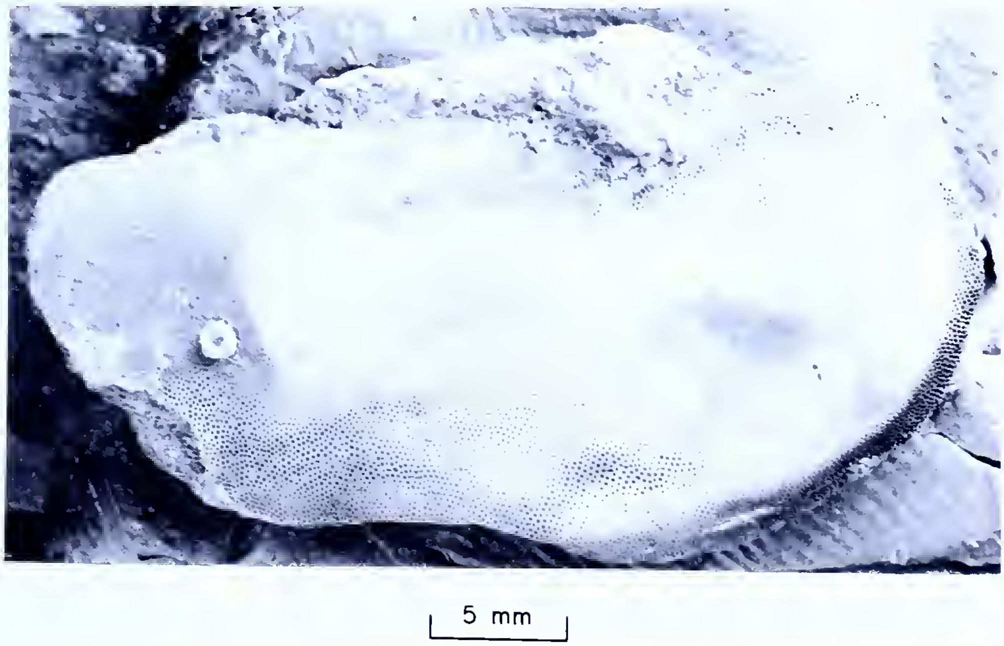

Figure 4. ***Deltodus,*** **showing porous surface, McConnells Mills.**

or ratfish. These teeth were apparently used for grinding and crushing the hard-shelled invertebrates that were the basic diet of the ancient Chimaerans (Lund, 1970).

The most unusual fossil found in the Vanport at the Lawrence County localities is a large fish spine from the McConnells Mill outcrop (Figure 5). The spine is conical and flattened and approximately 5 cm long. Except for a smooth proximal end, it has a scaly, "beadlike" covering over most of its length. The spine is nearly identical to the curved specimen of *Xystracanthus* illustrated in Lesley (1890, p. 1283). Romer (1966) assigns such spines to the hybodontoid shark *Physonemus*. To the best of our knowledge, this is the first documented occurrence of this genus in the Vanport Limestone. *Physonemus* has been previously reported from Carboniferous rocks in the mid-continent region.

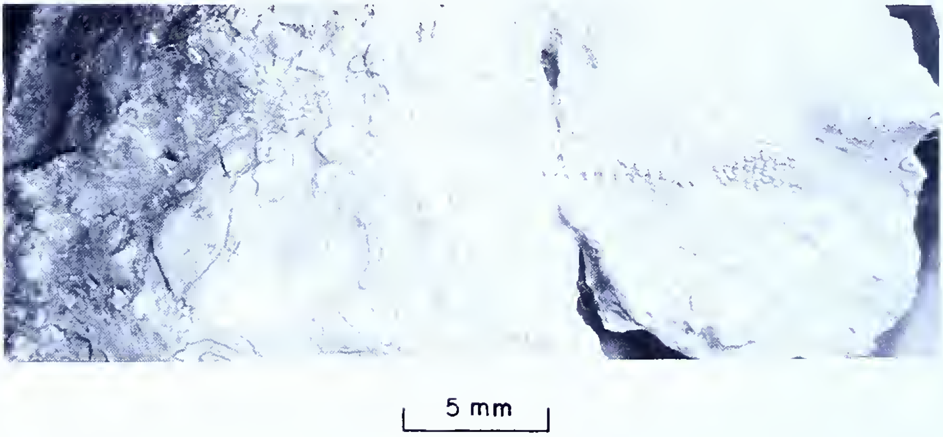

Figure 5. ***Physonemus*, showing "beadlike" covering on spine, McConnells Mills.**

The authors thank Dr. Robert Hinds, Slippery Rock University, and Dr. Steve Bill, formerly at Slippery Rock, for supervising the original research. Drs. John Harper and Jon Inners of the Pennsylvania Geological Survey, and Ms. Kathleen Abel, formerly with the Survey, assisted in preparing the article.

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magnetic susceptibility of precambrian basement rocks in northwestern pennsylvania

The Oil and Gas Geology Division of the Pennsylvania Geological Survey has obtained measurements of the magnetic susceptibilities of selected samples of Precambrian basement rocks from northwestern Pennsylvania (Figure 1). Samples for which susceptibility measurements were obtained were collected from the Survey's core and sample libraries in Pittsburgh. Susceptibility measurements were made by Dr. Hallan C. Noltimier, Professor of Geology at Ohio State University, at the request of Donis Snellenberger, geophysicist with the Mitchell Energy Corporation, Columbus, Ohio.

Magnetic susceptibility is a measure of the degree to which a material is attracted to a magnet. The degree of magnetization of rocks is the product of their susceptibility and the strength of the earth's magnetizing field. Results of the susceptibility measurements reveal the relative magnetic strength of the Precambrian basement in northwestern Pennsylvania. When obtaining or interpreting magnetic data in that region, the data presented here can aid in determining if any observed anomalies are structural or compositional in nature. The magnetic susceptibility values presented here also compliment the data presented in Pennsylvania Geological Survey Information Circular 62, *The Precambrian in the Subsurface of Northwestern Pennsylvania and Adjoining States,* by T. E. Saylor.

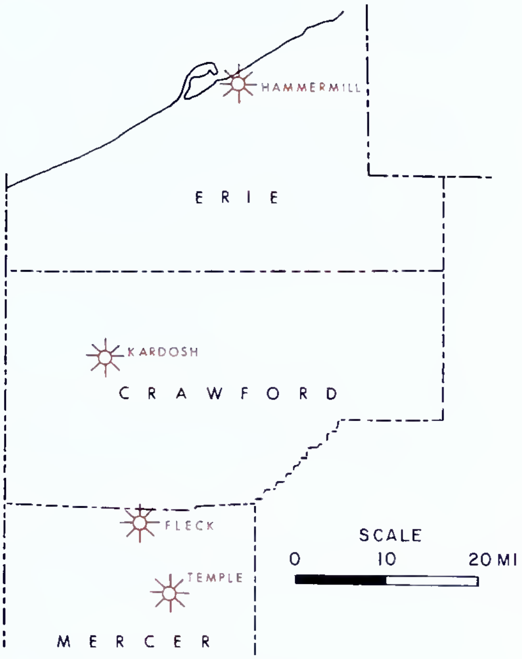


Figure 1. Location map.

LITHOLOGY AND MAGNETIC SUSCEPTIBILITY OF PRECAMBRIAN BASEMENT ROCKS FROM NORTHWESTERN PENNSYLVANIA

Well name	*Location*	*Lithology*	*Susceptibility (gauss/oersted)*
Hammermill No. 2	Erie Co.	Biotite gneiss intruded by microcline granite; magnetite content = 0-<1%	2.52 x 10^{-5}
Kardosh No. 1	Crawford Co.	Quartz-biotite gneiss; abundant hematite grain coats; magnetite content = 1%	2.06 x 10^{-3}
Temple No. 1	Mercer Co.	Quartz-biotite gneiss; numerous lenses and veins of biotite granite; magnetite content = 1-2%	1.46 x 10^{-4}
Fleck No. 1	Mercer Co.	Quartz-biotite gneiss; numerous lenses and veins of biotite granite; magnetite content = 1-2%	1.21 x 10^{-4}

SURPLUS TOPOGRAPHIC MAPS

The Survey has accumulated a quantity of outdated 7½-minute-quadrangle topographic maps for northern Pennsylvania. We are offering them, in limited numbers, to teachers and troop leaders.

If you are interested in receiving a limited quantity of these maps, write to the Department of Environmental Resources, Bureau of Topographic and Geologic Survey, P. O. Box 2357, Harrisburg, PA 17120. Maps will be supplied as long as they last on a first-come, first-served basis. Orders for specific quadrangles cannot be accepted.

CHANGES WITHIN THE U.S. MINERAL INDUSTRY

by Samuel W. Berkheiser, Jr.
Pennsylvania Geological Survey

Two significant new publications dealing with the mineral problems and outlook of the United States mining community have recently become available. *The Mineral Position of the United States: the past fifteen years* (U.S. Bureau of Mines, 1986) is the 1985 Annual Report of the Secretary of the Interior and contains a review of the changes that have taken place in the mineral position of the nation since the Mining and Minerals Policy Act was enacted by Congress in 1970. This 45-page report is available free while supplies last from the U.S. Bureau of Mines, Division of Publications, 4900 LaSalle Road, Avondale, MD 20782-3393. Some of the major conclusions in this report are listed below:

—the U.S. mineral industry is undergoing significant structural change,
—less of the basic metals are needed, although the need for construction materials to build new infrastructure and maintain roads, bridges, and buildings is expected to increase,
—the outlook for increased growth is better for the nonmetallic minerals than for the basic metals, but the growth in demand for advanced metals or rare-earth metals could be considerable,
—two countries that may change the pattern of worldwide demand for and supply of minerals are China (producer) and the U.S.S.R. (potential consumer),
—new technology will play an increasingly important role in the competition for world markets, and
—U.S. companies may have to become more multinational, especially as joint ventures with foreign partners, risk-sharing arrangements, and diversification become more common.

Eugene N. Cameron, the author of *At the Crossroads—The Mineral Problems of the United States* (published by John Wiley and Sons, 1986), takes a somewhat contrasting position regarding the future of the mineral industry of the United States and elucidates both some familiar and some new mineral trends. By systematically examining the role of mineral resources (both fuel and nonfuel) in our economy, including their nature, uses, reserves, and the outlook for future supplies, Cameron concludes that domestic policies must be modified to create an environment more favorable to the discovery and development of new mineral deposits. "Otherwise the remainder of the century will see a decline in the U.S.'s ability to supply its mineral needs from its own resources. Decline in industrial strength and diminished national security will inevitably follow."

From a supply-and-demand standpoint, the future of Pennsylvania's current annual $800 million nonfuel-mineral industry appears brighter than ever. However, a balanced approach to mineral development and environmental conservation will be needed if Pennsylvania is to continue as a major supplier of quality mineral commodities.

REFERENCES

Cameron, E. G. (1986), *At the crossroads—The mineral problems of the United States,* New York, John Wiley and Sons, 320 p.

U.S. Bureau of Mines (1986), *The mineral position of the United States: the past fifteen years,* 1985 Annual Report of the Secretary of the Interior Under the Mining and Minerals Policy Act of 1970, U.S. Department of the Interior, 45 p.

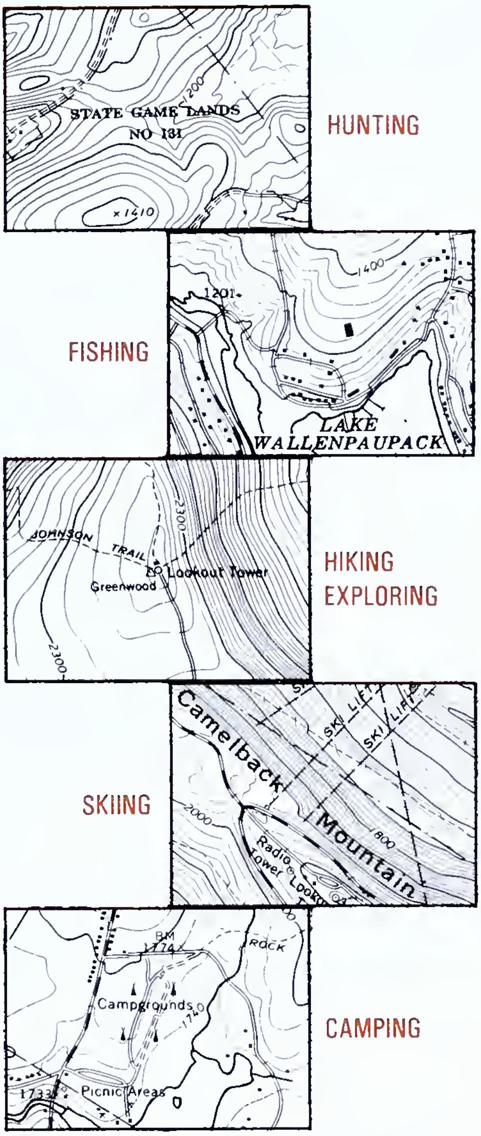
New Price for Oil and Gas Base Maps

In 1985, the Pennsylvania Geological Survey made available to the public a series of 7½-minute oil and gas base maps. These maps, which are compiled on 1:24,000-scale topographic bases, replaced the 15-minute series of base maps that had been on sale since 1970. The 7½-minute maps cover the oil and gas fields of western Pennsylvania and the areas of central and eastern Pennsylvania where exploratory drilling has occurred.

The 7½-minute oil and gas base maps are available to the public as ozalid prints. Effective June 1, 1987, the price of the maps is $3.75 each plus shipping costs.

Details for purchasing the maps can be obtained by contacting the Pennsylvania Geological Survey, Oil and Gas Geology Division, 121 South Highland Avenue, Pittsburgh, PA 15206-3988, telephone 412-645-7057. When requesting copies of the maps, please provide the 7½-minute topographic map name of each map desired.

7½-MINUTE TOPOGRAPHIC MAPS



(Maps shown above have been reduced by 30 percent)

During 1986, twenty-two 7½-minute topographic maps were photorevised by the U.S. Geological Survey. This was accomplished as part of the U.S. Geological Survey-Pennsylvania Geological Survey cooperative program to prepare and maintain topographic map coverage for Pennsylvania.

The 7½-minute "topos" are used for areas where detailed base maps are needed. They are most often utilized by professionals for geologic mapping, engineering planning, water-quality research, and ecological studies, but they are also widely used by campers, hikers, hunters, and other persons engaged in outdoor activities.

There are 879 topographic quadrangle maps for Pennsylvania, each covering an area 7½ minutes square (a minute is one-sixtieth of a degree in latitude and longitude). The map scale is 1:24,000 (one inch equals about 2,000 feet), and each quadrangle represents an area of between 49 and 71 square miles.

The twenty-two 7½-minute topographic maps photorevised for Pennsylvania during 1986 include Antrim, Blossburg, Blue Ridge Summit (Md.-Pa.), Crooked Creek, Crosby, Derrick City (Pa.-N.Y.), Emmitsburg (Md.-Pa.), Gleason, Jackson Summit (Pa.-N.Y.), Liberty, Mansfield, Morris, Nauvoo, Philadelphia, Ralston, Rathbun, Sayre, Tioga, Weedville, Westline, White Pine, and Wildwood Fire Tower.

Except for Blue Ridge Summit, Emmitsburg, and Philadelphia, the areas of photorevision are in north-central Pennsylvania.

The topographic maps can be obtained for $2.50 each by writing to U.S. Geological Survey, Map Distribution, Box 25286, Federal Center, Denver, CO 80225. Prepayment is required; checks should be made payable to *U.S.G.S.* For more information, contact the Pennsylvania Geological Survey library (NCIC Affiliate) at 717-783-8077.

New Staff of the Pennsylvania Geological Survey

Caron O'Neil

Caron O'Neil joined the Survey as Assistant Geological Editor in September 1986. Prior to this, she was a resident of Pittsburgh, where she attended the University of Pittsburgh. Caron started her post-high-school education as a chemical engineering major at Lehigh University. The jump to geology and the subsequent transfer to Pitt came 3 years later, after Caron took, and was taken by, her first geology course. She received a B.S. in geology (with a Math minor) in December 1981, and an M.S. in geology in December 1986.

Caron's geologic employment history includes three years as a teaching assistant, and two short-term contracts with the Department of Energy. Her teaching duties consisted of preparing and conducting physical geology, historical geology, geomorphology, and structural geology labs. The contract work involved lineament studies with the Morgantown Energy Technology Center.

Loretta Rossum

Loretta Rossum joined the staff of the Survey in April 1987. She will work primarily with the Environmental Geology Division as a Clerk Typist with additional assignments in the Administrative Division when needs arise.

Loretta is a native of Harrisburg and has attended school here and business college in Detroit, Michigan. While she was a student at John Harris High School she received the Powelson Business Award for academic achievement.

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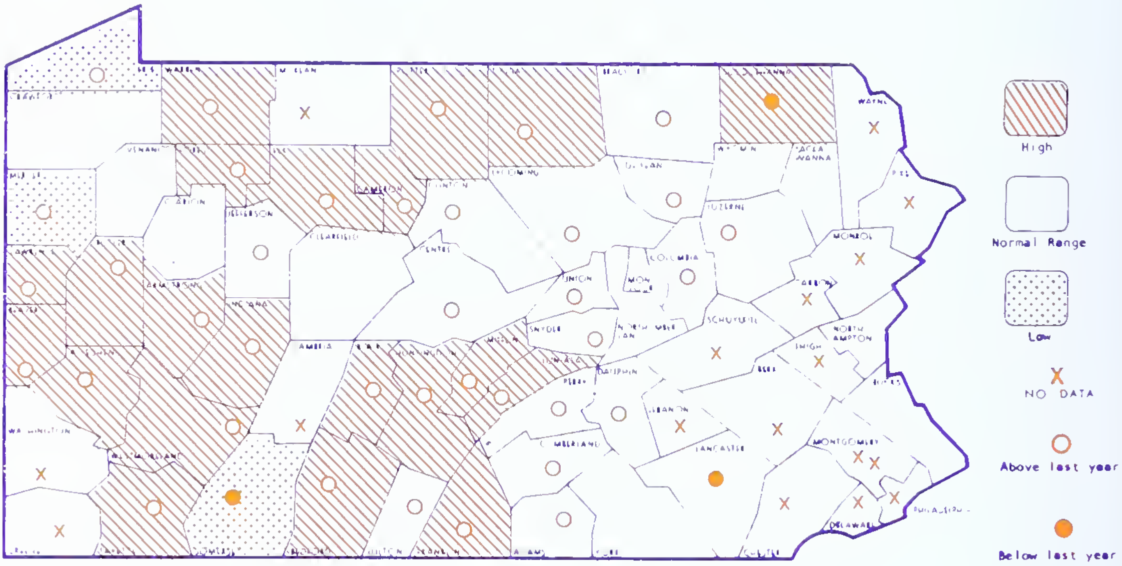
FOR
MAY 1987



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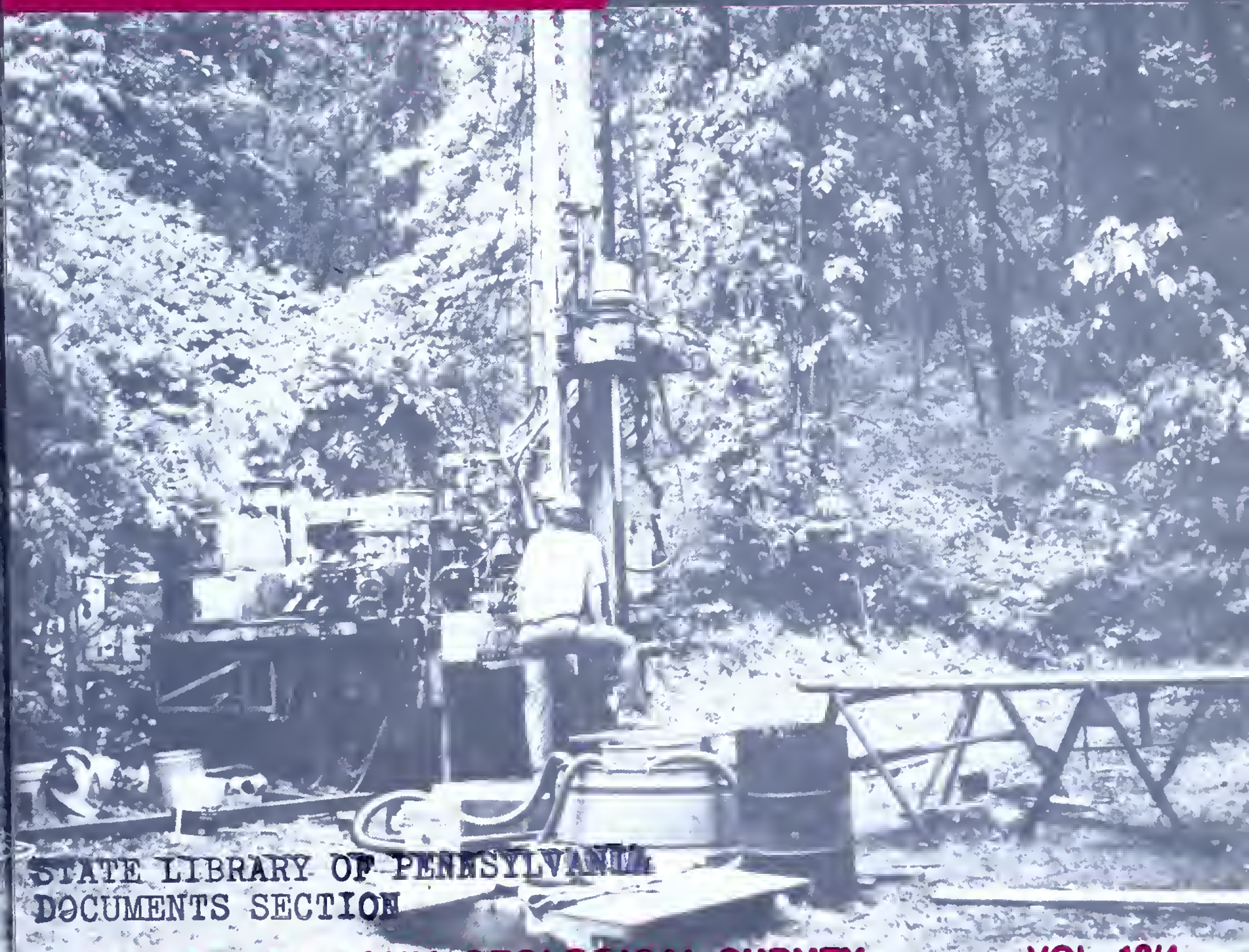

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VOL. 18/4

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ON THE COVER: Cooperative U.S. Geological Survey-Pennsylvania Geological Survey core-hole drilling in Jurassic York Haven-type diabase. The objective was to test a new model for heavy-metal enrichment during differentiation. Anticipated data-release date is late 1988. Photograph by R. C. Smith, II.

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Editor, Christine M. Dodge

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VOL. 18, NO. 4 **AUGUST 1987**

An Ethic of Research

Geologic research is the groundwork on which decisions for the effective utilization and management of our Commonwealth's plentiful mineral and groundwater resources and natural beauty are made.

This issue of *Pennsylvania Geology* proudly focuses on geological research conducted by our bureau and by all of the many geologists and hydrogeologists in the public, private, and academic sectors who investigate the geological nature of Pennsylvania. This year's compilation marks the completion of three decades of providing information on the geologic research being conducted in Pennsylvania, an annual service we intend to continue. In some quarters the word "research" is one to be avoided, an "ivory-tower" term with all that it suggests about withdrawal from reality and action. We do not accept that suggestion and do not avoid the word.

Research in geology in Pennsylvania is a necessary reality for us. It is the conscious action we take to study the surface and subsurface of our state so as to better understand and map its resources, hazards, and natural beauty. And in better understanding these geological features we can better discharge our duty to predict and advise for the future wise use and conservation of Pennsylvania's resources.

Our perspective in geological research is one undergirded by the recognition that we deal with an ever-changing, dynamic earth, developed through eons of geologic time. We engage in research to provide the information not only to solve today's problems, but also the problems 10 years, 50 years, and 150 years from today. The results of the research we have conducted in past decades is the information we use in answering today's problems. But as our population grows and we use more and more of the available land surface, we must continue to do even more detailed investigations so as to allow us to harmoniously utilize our land, water, and mineral resources.

As we conduct our geological research, we find answers to current relevant geological problems. Yet we are faithful that basic geological research will always provide a return valuable in future decades. It is by the careful compilation of geologic data, and by its painstaking evaluation and interpretation, that our geological research will benefit all Pennsylvanians. History has repeatedly shown that serendipity, the aptitude for making unplanned and fortunate discoveries, will occur in geological research in Pennsylvania whether by our bureau or by the many other researchers listed herein.

Donald M Hoskins

State Geologist

GEOLOGIST, TEACHER, FRIEND

GEORGE H. CROWL

1910–1987

George H. Crowl was, above all else, a field geologist who did his best teaching with students and colleagues in the field, where he loved to ask "Well, what the hell is it?" Always willing to play the devil's advocate, he improved the work of many geologists in Pennsylvania. George had a contagious enthusiasm about geology that inspired others to seek better answers and to produce superior geologic maps. He also had a wry sense of humor that kept many from taking themselves too seriously.

George was born in Wooster, Ohio. He obtained a B.A. degree from Wooster College in 1932 and an M.A. from Harvard in 1934. From 1935 through 1939, George worked for the oil industry in the Midwest, Kuwait, Arabia, and Venezuela. In 1939 he commenced a teaching career, which was interrupted only by a brief return to petroleum investigations in Wyoming and Utah (1944–46), and graduate work which led to the Ph.D. degree from Princeton in 1950. George taught at Rutgers University, Vanderbilt University, Hamilton College, and The Pennsylvania State University prior to going to Ohio Wesleyan University in 1947. He retired from full-time teaching at Ohio Wesleyan in 1975. George remained active following retirement, both as a teacher and as a field geologist.

A stratigrapher and structural geologist in his earlier days, George developed an interest in glacial geology and worked in Greenland and Prince Edward Island on this subject prior to starting work in Pennsylvania in 1968. His first work for the Pennsylvania Geological Survey involved mapping the glacial geology of the Delaware River valley, published in 1974 as General Geology Report 60. He initiated peat bog and lake coring, which resulted in the first radiocarbon dates in northeastern Pennsylvania. His interest in glacial problems of Pennsylvania stimulated, George retraced, partly at his own expense, the late Wisconsinan border across the eastern part of the state (General Geology Report 71). He then pursued some of the problems of the pre-Wisconsinan drift, resulting in significant reevaluations of ice-advance limits. George was scheduled to continue this work at the time of his death.

Greatly interested in the problems of Pennsylvania geology and always willing to ask difficult questions, George Crowl was a true geologist, teacher, and friend known and loved by many. George, we will all miss you.

GEOLOGICAL RESEARCH IN PENNSYLVANIA

1987

Introduction

This publication, the thirtieth annual report in its series, contains a listing of all known current geological research in Pennsylvania and all known reports published during the past year. Because of the large number of projects reported to us, we condense the descriptions to fit available space.

We have requested each person to provide an anticipated completion date (ACD) for each project. The anticipated completion date is the author's estimate of the date when the project will be finished; additional time should be allowed for publication of the report.

If you wish more information on a project described herein, please write directly to the author; most of these projects will not be published by the Pennsylvania Geological Survey inasmuch as most are not Survey-sponsored projects.

The listings are grouped into major categories of research to facilitate your search for information on a particular subject. Reports published are listed alphabetically by author. As in all compilations, there may be omissions; this is unintentional.

Additional copies of this report may be obtained by writing to the Bureau of Topographic and Geologic Survey, Department of Environmental Resources, P. O. Box 2357, Harrisburg, Pennsylvania 17120.

Areal Geology

T. M. BERG, Pa. Geol. Survey, and M. L. O'NEAL, J. LUNDY, and J. B. LESSMAN (former summer assistants, Pa. Geol. Survey). **Warren County Geologic Map.** This revised geologic map at a scale of 1:50,000 will be included as the base map for the cooperative Pa. Geol. Survey-U.S. Geol. Survey water resource report on Warren County. In addition to Upper Devonian, Mississippian, and Pennsylvanian bedrock units, the map will show areas of alluvium, outwash, and other stratified-drift deposits. ACD: 1988.

J. B. EPSTEIN and P. T. LYTTLE, U.S. Geol. Survey, and G. G. LASH, SUNY, Coll. at Fredonia. **Geology of the New Tripoli Quadrangle, Pa.** ACD: Dec. 1987.

R. T. FAILL, Pa. Geol. Survey. **Studies of the Piedmont Province in Pennsylvania.** Projects and activities will be directed towards understanding the geologic history, tectonics, and origins of this terrane. Emphasis will also be placed on mineral resources, groundwater, and environmental concerns.

A. J. FROELICH, Project Chief, U.S. Geol. Survey. **Early Mesozoic Evolution of the Eastern United States.** Field geologic, petrographic, and geochemical studies of early Mesozoic diabase sheets continue in the Gettysburg and Newark basins. Two core holes were drilled in the Gettysburg basin to test mineralization models. Field mapping of the Hammer Creek Formation in the "Narrow Neck" between the Gettysburg and Newark basins was extended into the Reading quadrangle. Specific plans beyond May 1987 are to complete the diabase coring program, select samples for petrographic and chemical analysis, and continue topical and regional studies of the diabase and its differentiates. ACD: FY 1988.

F. W. HALL, Indiana Univ. of Pa. **Bedrock Geology of the Duncansville-Frankstown Area, Pa.** Preliminary geologic mapping at 1:24,000 scale has revealed previously unmapped faults and third-order folds. ACD: 1988.

DAVID HOPKINS, J. E. Baker Co., and G. R. GANIS, TETHYS Consultants, Inc: **Lower Paleozoic Rocks of the West York Quadrangle.** Lower Paleozoic carbonates and clastics are being mapped between the Stoner fault and the Mesozoic overlap. Paleontologic support is being provided by the U.S. Geol. Survey. ACD: Dec. 1987.

J. D. INNERS, Pa. Geol. Survey. **Geology and Mineral Resources of the Hazleton Quadrangle, Luzerne, Carbon, and Schuylkill Counties, Pennsylvania.**

P. C. LYONS, Project Chief, U.S. Geol. Survey. **Middle and Upper Pennsylvanian Studies, Appalachian Basin.** Field studies will be conducted and coal, underclay, and sandstone samples will be collected in the Broad Top and Anthracite coal fields of Pennsylvania. The purpose of the study is to track the paleogeothermometry using reflective and H/C and O/C atomic ratios of vitrinite, illite crystallinity of the underclays, and feldspar geothermometry of associated sandstones. The results will be related to Pennsylvanian sedimentation, stratigraphy, structure, and tectonism in the northern part of the Appalachian basin. ACD: FY 1989.

Economic Geology

S. W. BERKHEISER, JR., and R. C. SMITH, II, Pa. Geol. Survey. **Additional Occurrences of Specialty-Use Silica in Pennsylvania.** The purpose of the investigation is to identify and characterize Cambrian-age clastic resources within the South Mountain area of Adams, Cumberland, and

Franklin Counties. Additional data concerning the thickness and quality of selected quartz veins and a few other sandstones are also included. Results of the analyses are scheduled to be open-filed in Fall 1987. A core hole through 850 feet of sandstone and quartzite may be drilled in late 1987. ACD: Dec. 1987.

S. W. BERKHEISER, JR., and R. C. SMITH, II, Pa. Geol. Survey. **Mineral Fillers of the Piedmont Physiographic Province of Pennsylvania.** Reconnaissance investigations of potential mica, talc, silica, and carbonate mineral fillers in the Piedmont physiographic province of Pennsylvania. These studies are preliminary in nature and support anticipated new mapping programs in the region. ACD: Ongoing.

S. W. BERKHEISER, JR., and R. C. SMITH, II, Pa. Geol. Survey. **Reconnaissance Investigations and Analyses of High-Purity Carbonate Resources in Pennsylvania.** Preliminary reconnaissance investigations with the object of updating and identifying new high-purity carbonate resources for use in the acid-mitigation fields. The Valley and Ridge physiographic province contains numerous carbonate sequences of Cambrian through Devonian age. ACD: Ongoing.

W. A. BRAGONIER, Rochester and Pittsburgh Coal Company, and A. D. GLOVER and J. G. PHILLIPS, Pa. Geol. Survey. **Coal Resources of Armstrong County, Pennsylvania—Part 1, Coal Crop Lines, Mined-Out Areas, and Structure Contours.** Published and unpublished data will be used to prepare a series of maps including (1) separate crop-line maps for each principal coal seam showing areas of strip and deep mining, and (2) composite maps showing the crop lines of all principal coals, as well as structure contours and fold axes. ACD: 1987.

W. A. BRAGONIER, Rochester and Pittsburgh Coal Company, and A. D. GLOVER and J. G. PHILLIPS, Pa. Geol. Survey. **Coal Resources of Indiana County, Pennsylvania—Part 1, Coal Crop Lines, Mined-Out Areas, and Structure Contours.** Published and unpublished data will be used to prepare a series of maps including (1) separate crop-line maps for each principal coal seam showing areas of strip and deep mining, and (2) composite maps showing the crop lines of all principal coals, as well as structure contours and fold axes. ACD: 1987.

C. H. DODGE, Pa. Geol. Survey. **Coal Resources of Elk County, Pennsylvania—Part 1, Coal Crop Lines, Mined-Out Areas, and Structure Contours.** Detailed geologic mapping of the coal-bearing strata (Pottsville, Allegheny, and Glenshaw Formations) of Pennsylvanian age. Emphasis is on the major coal-bearing structural basins. A series of maps will be prepared including (1) separate crop-line maps for each principal coal seam showing areas of strip and deep mining, and (2) composite maps showing the crop lines of major and minor coals, as well as structure contours and fold axes. ACD: 1990.

A. D. GLOVER, Pa. Geol. Survey. **Coal Resources of Jefferson County, Pennsylvania—Part 1, Coal Crop Lines, Mined-Out Areas, and Structure Contours.** Published and unpublished data will be used to prepare a series of maps including (1) separate crop-line maps for each principal coal seam showing areas of strip and deep mining, and (2) composite maps showing the crop lines of all principal coals, as well as structure contours and fold axes. ACD: 1989.

J. A. HARPER, Pa. Geol. Survey. **Geology of Leidy Gas Field, Clinton and Potter Counties, Pennsylvania.** ACD: Mar. 1988.

L. J. LENTZ, Pa. Geol. Survey. **Coal Resources of Greene County, Pennsylvania—Part 2.** Purpose is to provide a coal-geology and chemistry data base for Greene County that will generate reasonable reserve and quality estimates of the coal resources in the county. ACD: Ongoing.

S. T. PEES, Samuel T. Pees and Assoc. **Aspects of the Petroleum Geology of the Lockport Fm. in Western Crawford County, NW Pennsylvania.** Porosity zones and hydrocarbon shows are integrated with structural and stratigraphic interpretations of the Lockport Formation. The study involves over 700 control wells in a 700-square-mile area in northwestern Pennsylvania. ACD: Sept. 1987.

G. R. ROBINSON, Project Chief, U.S. Geol. Survey. **Metallogeny of the Early Mesozoic Basins of the Eastern United States.** A cooperative study with A. J. Froelich (U.S. Geol. Survey) and R. C. Smith, II (Pa. Geol. Survey) involving sampling, drill coring, and geochemistry of selected Mesozoic diabase sheets in Pennsylvania. Papers submitted for a workshop on the geology of the early Mesozoic basins of the eastern United States, which was held in May 1987, will be published as U.S. Geological Survey Bulletin 1776. ACD: FY 1988.

J. B. ROEN, Project Chief, U.S. Geol. Survey. **Paleozoic Black Shales, Appalachian Basin.** Isopach, structure, and drilling depth maps for the Utica and Antes Shales, potential hydrocarbon source beds in the northern Appalachian basin, have been completed. Stratigraphic cross sections showing the Antes and Utica Shales and related rocks are complete. Collection of surface and subsurface samples and geochemical analyses have been completed. The final report, which includes an estimation of the source-rock resource potential, is being prepared. ACD: FY 1986.

J. R. SHAULIS, Pa. Geol. Survey. **Coal Resources of Somerset County, Pennsylvania—Part 1, Coal Crop Lines, Mined-Out Areas, and Structure Contours.** Published and unpublished data will be used to prepare a series of maps including (1) separate crop-line maps for each principal coal seam showing areas of strip and deep mining, and (2) composite maps showing the crop lines of all principal coals, as well as structure contours and fold axes. ACD: 1988.

V. W. SKEMA, Pa. Geol. Survey. **Coal Resources of Clearfield County, Pennsylvania—Part 1, Coal Crop Lines, Mined-Out Areas, and Structure Contours.** Detailed geologic mapping of the coal-bearing strata of Pennsylvanian age. Emphasis is on the major coal-bearing structural basins. A series of maps will be prepared including (1) separate crop-line maps for each principal coal seam showing areas of strip and deep mining, and (2) composite maps showing the crop lines of major and minor coals, as well as structure contours and fold axes.

R. C. SMITH, II, and J. H. BARNES, Pa. Geol. Survey. **Geology and Mineralogy of the Reading Prong, Berks, Bucks, Lehigh, and Northampton Counties, Pennsylvania.** Despite numerous interruptions, progress has been made in the contouring of data collected by portable gamma-ray spectrometer in 1981 at selected sites, and in manuscript preparation. ACD: 1988.

R. C. SMITH, II, and S. W. BERKHEISER, JR., Pa. Geol. Survey, and D. T. HOFF, Pa. Historical and Museum Comm. **Locations and Analyses of Selected Early Mesozoic Copper Occurrences in Pennsylvania.** Twenty-five composite samples from 17 different locations representing a wide variety of copper occurrences in the early Mesozoic basins of Pennsylvania have been analyzed for Cu, Au, Ag, Co, Ni, Mo, As, and Bi. Samples contain as much as 0.26 oz/t Au and 6.8 oz/t Ag. The samples having the highest Au contents are from low-Fe contact skarns in the Heidlersburg area of the Gettysburg basin that are near intrusions of both York Haven-type diabase and later Rossville-type diabase. ACD: 1987.

R. W. STANTON, Project Chief, U.S. Geol. Survey. **Coal Petrology.** Summary reports are being prepared for Pennsylvania, West Virginia, and Virginia on work that relates nondestructive testing to the prediction of coal washability characteristics of the Lower Freeport(?) coal beds. Most fundamental to this study is further enhancement of facies analysis of coal. Paleobotanical analyses of samples of the Upper Freeport, Pittsburgh, Lower Kittanning, and other coals reveal that assemblages of preserved plant tissue compressions in the coal (vitrain or fusain) correlate well to lithofacies of the coal bed. ACD: FY 1989.

A. M. STERNAGLE, Pa. Dept. of Transportation. **History of the Blair and Huntingdon Counties Iron Industry.** Study and history of early iron-making practices (charcoal and coke fuels), with special emphasis on the rock units mined. To date furnace sites have been located and the ore banks are being located. ACD: 1988.

T. S. WHITE and ALAN DAVIS, Pa. State Univ. **An Evaluation of Sulfur Forms and Pyrite Morphology in the Upper and Lower Clarion Coals** [Piney Twp., Clarion Co.]. The need to reduce sulfur levels in cleaned coal requires a better understanding of the distribution of sulfur forms and pyrite morphology in the seams. This project characterizes these parameters in a high-volatile bituminous coal. ACD: Spring 1988.

T. S. WHITE and ALAN DAVIS, Pa. State Univ. **Regional Topographic Controls on the Modes of Occurrence and Distribution of Sulfur in the Lower Kittanning Seam** [north-central and central Pa.]. A series of sampling traverses were made from paleotopographic low areas onto the Kane High. Sulfur forms, sulfur distribution, and modes of occurrence of pyrite will be determined to establish any regional trends. Local variations will be identified. ACD: Spring 1988.

Engineering Geology

S. R. MICHALSKI, R. E. GRAY, L. J. WINSCHEL, and R. W. BRUHN, GAI Consultants, Inc. **Engineering Analysis and Evaluation of the Glen Burn Mine Fire** [Northumberland Co.]. The boundaries and characteristics of the Glen Burn mine fire, which occupies the abandoned workings of four anthracite coal mines in the Western Middle coal field near Shamokin, Pa., are being defined. Installation of approximately 200 monitoring boreholes will be completed in early June 1987. ACD: Spring 1988.

Environmental Geology

D. D. BRAUN, Bloomsburg Univ., J. D. INNERS, Pa. Geol. Survey, N. D. GILMEISTER, Bloomsburg Univ., and J. P. WILSHUSEN, Pa. Geol. Survey. **Landslides and Cut-Slope Failures in Northeastern Pennsylvania.** ACD: Mar. 1988.

S. S. HARRISON, Allegheny Coll., LORI LESNEY, Kent State Univ., and MARTHA LESSESKI, Koppers Corp. **Investigation of Lead in Soils and Groundwater Beneath a Skeet- and Trap-Shooting Facility** [Crawford Co.]. The concentration of lead in the fallout zone at the shooting range was examined. Although lead concentrations were very high in the upper few inches of soil, concentrations declined rapidly with depth. No elevated lead concentrations were found in groundwater collected approximately 10 feet below the surface. ACD: June 1987.

S. A. HAYNES, R. C. SMITH, II, L. T. CHUBB, and MARK GLENN (summer assistant), Pa. Geol. Survey. **Reconnaissance for Radon-Prone Areas in the Mesozoic-Age Sedimentary Basins of Bucks County.** Carborne gamma-flux measurements covering nearly 200 miles of road have been completed in central and southern Bucks County. Nine rock and soil samples have been analyzed for uranium content. Preliminary results indicate at least one previously undescribed uranium occurrence located in the Stockton Formation northeast of Newtown. ACD: Sept. 30, 1987.

TERESA KAKTINS, Barron Hill Consultants, M. F. BUCEK, Bucek and Ebaugh, and DeWAYNE CAMPBELL, U.S. Forest Service (ret.). **Stream Renovation for Accumulation of Limestone Aggregate** [Antes Creek near Jersey Shore, Pa.]. Aggradation of Antes Creek by limestone aggregate from a mining operation has significantly altered stream morphology with adverse physical effects on trout habitat. Changes include widening and shallowing at riffles, pool filling, and spawning bed particle shape. A renovation plan is under design. ACD: 1992.

P. D. KNUTH, Edinboro Univ. and Coastal Research Assoc., Inc. **Lake Erie Bluff Recession Data Update.** Control points established 1 km apart in 1982 to measure future recession are being relocated. Measurement of these points during 1986-87 provides 5-year recession rates in bluff crests. Additional points have been established at 0.5-km intervals. ACD: May 1987.

W. E. KOCHANOV, Pa. Geol. Survey. **Sinkholes and Karst-Related Features of Berks County, Pennsylvania.** ACD: Dec. 1987.

W. E. KOCHANOV, Pa. Geol. Survey. **Sinkholes and Karst-Related Features of Lebanon County, Pennsylvania.** ACD: Dec. 1987.

W. E. KOCHANOV, Pa. Geol. Survey. **Sinkholes and Karst-Related Features of Northampton County, Pennsylvania.** Nine 7½-minute quadrangle maps show the carbonate geology and locations of sinkholes, karst features, and surface mines in the county. A computer inventory is currently being developed. The report will be available in an open-file format. ACD: June 1987.

C. R. LEMIEUX and T. W. GARDNER, Pa. State Univ. **Infiltration and Runoff Characteristics of a Reclaimed Surface Mine, Moshannon, PA.** Infiltration tests are conducted on four minesoils of different ages to examine the relationship between infiltration and rainfall intensity. Data collected during the tests are used to parameterize the runoff model (ANSWERS). Model results are evaluated against measured runoff. ACD: June 1987.

A. W. ROSE, A. R. HUTTER, JOHN WASHINGTON, and E. J. CIOLKOSZ, Pa. State Univ. **Geological and Pedological Controls on Radon in Soil Gases** [central Pa. and other regions]. Gases in soils over limestones contain 200 to 2,000 picocuries per liter radon, with high but variable values in soils over fracture traces. Controls are being investigated in more detail. ACD: 1990.

F. J. VENTO, Clarion Univ. of Pa., P. T. FITZGIBBONS, Univ. of Pittsburgh, and J. ERNISSEE, Clarion Univ. of Pa. **Paleoclimate and Holocene Age Paleosol Development Within the Susquehanna River Drainage Basin.** Present studies funded by the National Park Service and the Bureau of Historic Preservation involve radiometric dating of the paleosols, phytolith and pollen analyses, and paleosol development as it relates to paleoclimate, stream regime, and archaeological site location. ACD: July 13, 1988.

General Geology

D. M. HOSKINS and SANDRA BLUST, Pa. Geol. Survey. **The Geology of William Darby.** A chapter on William Darby is being prepared for a Geological Society of America Special Paper on the history of geology in the American Southwest.

D. M. HOSKINS and SANDRA BLUST, Pa. Geol. Survey, and PATSY GERTSNER, Cleveland Medical Library Assoc. **The Geology of H. D. Rogers.** A chapter is being prepared for P. Gertsner's biography of H. D. Rogers dealing with the scientific achievements of Rogers during the First Pennsylvania Geological Survey.

C. H. SHULTZ, ed., Slippery Rock Univ. and Pittsburgh Geol. Soc. **The Geology of Pennsylvania.** This book-writing project is being developed and managed by the Pittsburgh Geological Society. The book will be published by the Pennsylvania Geological Survey; it will be of large format and about 600 pages long with 16 pages of color. Coverage is encyclopedic and is organized into 57 chapters grouped into 10 parts. Writers are about equally divided among government, industry, and academia. Most writing units have undergone editorial review and have been revised or revisions are pending. It is anticipated that all manuscripts will be submitted to the Pennsylvania Geological Survey for copy editing, drafting, and layout by early 1988. ACD: Early 1989.

Geochemistry

MICHAEL BIKERMAN, MICHAEL HARTLEY, RALPH FEATHER, JR., and C. D. McNAUGHTON, Univ. of Pittsburgh. **Geochronological Study of Appalachian Uplift Using K-Ar and Fission Track Methods** [central Pa.]. Initial sample collection begun. Feather is learning fission-track techniques at R.P.I. Otherwise in an early state. ACD: 1989–90.

C. B. CECIL, Project Chief, U.S. Geol. Survey. **Geochemical Environments.** Selected samples of Pottsville and Allegheny Series coal beds and associated rocks are being collected from Indiana County and analyzed. Palynological data from these samples are being compared to the Pennsylvanian stratotype. In addition to biostratigraphic information, paleoecological interpretations are being formulated for selected coal beds. These and other data are being developed as part of predictive model development for the occurrence and quality of coal. ACD: FY 1989.

L. D. CECIL, U.S. Geol. Survey, R. C. SMITH, II, Pa. Geol. Survey, M. A. REILLY, Pa. Dept. of Environ. Resources, and A. W. ROSE, Pa. State Univ. **Radium and Radon Occurrence in Ground Water of the Chickies Formation, Southeastern Pennsylvania.** The reconnaissance sampling phase of the project was completed in January 1987. Nineteen of the 51 well-water samples analyzed had combined radium-226 and radium-228 concentrations that exceeded the U.S. Environmental Protection Agency's maximum contaminant level of 5 picocuries per liter. ACD: July 1988.

K. R. CERCONE, JOHN TAYLOR, and NANCY DURIKA, Ind. Univ. of Pa. **Mineralogy of Fossil Shell Material in the Brush Creek Marine Interval, Glenshaw Formation, Conemaugh Group** [Indiana Co.]. Primary aragonite and magnesian calcite have been shown by staining and ultraviolet microscopy to occur at a single locality of the Brush Creek marine interval. Preliminary study suggests that trilobite skeletal material from this interval was originally composed of low-magnesium calcite. ACD: Oct. 1987.

R. B. FINKELMAN, Project Chief, U.S. Geol. Survey. **Coal Geochemistry.** Ninety-six samples in Pennsylvania have been analyzed for trace elements, 75 for ultimate and proximate analyses and equilibrium moistures. Presently work is continuing on geographical data. ACD: FY 1989.

P. P. HEARN, Project Chief, U.S. Geol. Survey. **Diagenesis of Authigenic K-Feldspar in Lower Paleozoic Carbonate Rocks of the Appalachian Basin.** High-precision radiometric, chemical, and isotopic analyses of 10 to 20 purified K-feldspar and quartz separates from feldspathized rocks from the southern, central, and northern Appalachians and the mid-continent area have been completed. The utility of authigenic K-feldspar in dating fluid-migration events and characterizing the chemical evolution of fluids in sedimentary basins is being evaluated. ACD: FY 1986.

C. D. LAUGHREY, Pa. Geol. Survey. **Geochemistry of Petroleum Source Rocks in Pennsylvania.** Petroleum source rocks will be identified and correlated to reservoir hydrocarbons through determinations of organic content, kerogen types, stable isotope chemistry, and compositions of solvent-extractable hydrocarbons and nonhydrocarbons. Thermal maturities will be determined from optical and physicochemical properties of kerogens and by mathematical modeling. ACD: May 1988.

J. M. McNEAL, Project Chief, U.S. Geol. Survey. **Sulfur Isotopes in Triassic Basins.** The results of sulfur-isotopic and chemical analyses of water and rock samples collected in FY 1985–87 from the York Haven and Zora Ring structures and the Newark basin in Pennsylvania will be evaluated in FY 1988. Collection and analysis of samples from other areas, specifically NURE stream-sediment and water-chemistry data for the Mesozoic basins, are well underway and will be completed and evaluated in FY 1988. ACD: FY 1988.

M. K. RODEN and D. S. MILLER, Rensselaer Polytechnic Inst. **Thermal and Burial History of the Tioga Ash Bed in the Appalachian Basin of**

Pennsylvania Based on Apatite Fission-Track Chronology. Eleven samples of Tioga Ash Bed (Bed B) have a range of apatite fission-track apparent ages from 153–238 ± 10 Ma. This indicates that the apatites have been reset from their depositional age of 380 Ma. Our model suggests that the Tioga Ash Bed has seen burial to a depth greater than 4 km, 115°C (assuming a geothermal gradient of 25°C/km). The apatites were cooled through the partial annealing zone at 220 Ma to produce their apparent fission-track ages. ACD: May 1988.

E. C. SPIKER, Project Chief, U.S. Geol. Survey. **Environmental Isotope Geochemistry.** A wide range of sedimentary problems in the Mesozoic black shales of the Newark basin will be addressed. Stable carbon isotope compositions are being used to determine the source of kerogen. Stable sulfur isotopes are being used to study sulfur cycling in order to determine open versus closed alkaline lake conditions during periods of shale deposition. ACD: FY 1992.

J. F. SUTTER, Project Chief, U.S. Geol. Survey. **Thermochronology.** Since May 1986 no work has been carried out in the Mesozoic basins of Pennsylvania in this project; however, a new project aimed at the timing of slaty cleavage development in the Martinsburg has been initiated. This involves the use of a laser microprobe for releasing argon from samples *in situ* and dating individual mineral grains that grew during the formation of the cleavage. ACD: FY 1989.

Geomorphology

T. W. GARDNER, MICHAEL GUEBERT, SHELTON ALEXANDER, and CHARLES THORTON, Pa. State Univ., and HAIYAN HU, Coll. of Geology, Wuhan, China. **Tectonic Geomorphology Along the Lower Susquehanna River and Adjacent Counties.** Historic seismic activity in the Lancaster County area suggests possible neotectonic activity and crustal deformation. Travertines in streams, morphometric analyses of landforms, and mapping of Susquehanna River terraces are being used to explore the possibility and nature of the neotectonic activity. ACD: 1989.

MICHAEL GUEBERT and T. W. GARDNER, Pa. State Univ. **The Relationship Between Remotely Sensed (SPOT) Data and the Infiltration/Runoff Characteristics of Surface Mined Land in Central Pennsylvania** [NW Centre Co.]. Ninety field tests reveal infiltration-capacity increases with decreasing grain size of spoil and with increasing vegetation cover. Clustering of SPOT data represents differences in type and percentage cover of both spoil and vegetation. ACD: June 1987.

P. D. KNUTH, Edinboro Univ. **Morphology of an Artificially Nourished Beach; Presque Isle State Park.** Two cycles of erosion are being examined in artificially placed coarse sands on a high-energy beach. ACD: Summer 1987.

J. B. RITTER and T. W. GARDNER, Pa. State Univ. **The Effect of Lithology on Sediment and Water Discharge from Reclaimed Watersheds During Drainage Basin Development** [west-central Pa.]. ACD: 1989.

G. H. THOMPSON, JR., Elizabethtown Coll., and W. D. SEVON, Pa. Geol. Survey. **River Bed Erosion in the Susquehanna River Gorge at Holtwood, Pa.** The process of potholing has been identified as assisting in hydraulic removal of bedrock blocks during flood episodes. We are continuing research on the specific mechanisms by which potholes originate and enlarge.

W. B. WHITE, Pa. State Univ. **Caves of Pennsylvania.** The object of the project is to prepare maps and descriptions of all known caves in Pennsylvania.

W. B. WHITE and E. L. WHITE, Pa. State Univ. **Karst Landforms in the Appalachian Mountains.** An ongoing effort to describe karst landscapes and to interpret their evolution and geological controls throughout the Appalachian Highlands. ACD: Ongoing.

Geophysics

J. D. PHILLIPS, Project Chief, U.S. Geol. Survey. **Geophysical Mapping of Early Mesozoic Basins.** A compilation of aeromagnetic data for the western Newark basin has been completed, and a compilation for the Gettysburg basin is being continued. Plans are to produce aeromagnetic and gravity contour maps for these basins in the near future. ACD: FY 1987.

Glacial Geology

D. D. BRAUN, Bloomsburg Univ., and WILLIAM BRENNAN, SUNY, Coll. at Geneseo. **Testing the Use of Secular Changes in Geomagnetic Declination for Correlation of Ice Margins Across the Appalachian Plateau** [north-central Pa. and south-central N. Y.]. Mapping of proglacial-lake-sediment distribution in Potter and Tioga Counties is complete. Initial surface sampling will be supplemented by subsurface sampling this year. Preliminary ice-margin correlation is underway presently. ACD: 1989.

D. D. BRAUN, Bloomsburg Univ., and J. D. INNERS, Pa. Geol. Survey. **The Extent and Age of Pre-Wisconsinan Glaciation in the Anthracite Region of Pennsylvania.** The extent of glaciation is being mapped by the presence or absence of glacial drift in strip-mine exposures. Drift stratigraphy and sampling for paleomagnetic determination should permit estimation of the number and age of ice advances into the region. ACD: 1989.

W. D. SEVON, Pa. Geol. Survey. **Mapping of Surficial Geology North of the Late Wisconsinan Glacial Limit, Northeastern Pennsylvania.** Mapping is being done at 1:24,000 scale and compiled at 1:100,000 scale. Fifty-nine quadrangles have been completed. Sand and gravel and till samples are being analyzed. ACD: 1989.

Hydrology

A. E. BECHER, U.S. Geol. Survey. **Ground-Water Flow Systems and Water Quality of the Gettysburg Area, Pennsylvania.** Groundwater resources in the Gettysburg National Military Park are vulnerable to contamination from organic solvents found in groundwater nearby and agricultural products applied to crop land. Flow systems have been defined and water quality is being evaluated. ACD: Fall 1987.

A. E. BECHER, U.S. Geol. Survey. **Ground-Water Resources of Cambrian and Ordovician Carbonate Rocks in the Valley and Ridge Province in Pennsylvania.** ACD: 1987.

T. F. BUCKWALTER, U.S. Geol. Survey, and M. E. MOORE, Pa. Geol. Survey. **Groundwater Resources of Warren County, Pa.** Countywide groundwater conditions will be evaluated. Extensive water-quality data will be used to determine impacts of oil and gas production on the resource. A revised geologic map will be included. ACD: Dec. 1988.

G. A. JOHNSON and T. E. SAYLOR, Buchart-Horn, Inc. **Detailed Subsurface Mapping of Fracture Closure in a Crystalline Bedrock Formation.** A surface electrical resistivity investigation conducted in the Marburg Schist of the Wissahickon Formation of south-central Pennsylvania was used to successfully map the closure of fracture apertures within the crystalline bedrock formation. In addition to fracture characterization, hydraulic conductivity relationships were established between the zone of open fractures (aquifer) and the zone of closed fractures (aquitard). ACD: Completed.

G. A. JOHNSON and D. J. WHALEN, Buchart-Horn, Inc. **Groundwater Modeling—A Management Tool.** A hydrogeologic investigation within the South Mountain complex of south-central Pennsylvania was performed to develop a groundwater management program. ACD: Completed.

T. A. McELROY, Pa. Geol. Survey, and D. R. WILLIAMS, U.S. Geol. Survey. **Geology and Water Resources of Indiana County, Pennsylvania.** Purpose is to evaluate the surface water and groundwater conditions throughout Indiana County and to determine the effect of coal mining and gas wells on the resources. A geologic map will be included. ACD: 1989.

C. A. SHUMAN, Pa. State Univ. **Fracture Studies and *In Situ* Permeability Testing with Borehole Packers** [Appalachian Plateau near Clearfield, Pa.]. To characterize the subsurface nature of a photolinear, fracture features exposed by a surface coal mine were analyzed. Fracture-trace and joint-study results showed a consistent northwest trend, whereas air-injection tests quantified the permeability variation of a uniform siltstone. ACD: May 1987.

R. A. SLOTO, U.S. Geol. Survey. **Ground-Water Flow in the Carbonate Rock of the Valley Creek Basin, Chester County, PA.** Detailed description of groundwater flow. A digital simulation model for the basin has been developed, geophysical logs have been run on 14 wells, and a basin water budget has been developed. ACD: Sept. 30, 1988.

K. L. VOGEL and DELORIS SPEIGHT, U.S. Geol. Survey. **Water Use in Chester County, Pennsylvania.** Study will provide a countywide, water-use data base to be utilized in assessing the effects of urbanization on groundwater and other water supplies. The data base is presently 90 percent complete. A microcomputer program is being developed for data management and subbasin water-budget assessments. ACD: Sept. 30, 1987.

D. S. YANNACCI, Pa. Geol. Survey, and DENNIS LOW, U.S. Geol. Survey. **Aquifer Characteristics of the Rocks of Pennsylvania.** A comprehensive summary of the characteristics of the aquifers of Pennsylvania will be developed. Information studied will include well yield, groundwater quality, flow, recharge and discharge, and lithology. ACD: June 1989.

Igneous and Metamorphic Petrology

P. A. COPPOCK, GEORGE MYER, M. L. HILL, and DAVID GRANDSTAFF, Temple Univ., and FRANK ROBERTS, Del. Co. Christian School. **Petrology and Structural Fabric of the Castle Rock Ultramafic Enclave** [Media quad.]. Initial field and laboratory results suggest a layered cumulate (orthopyroxene) with overprinting (amphibole) associated with polymict serpentinite and serpentine enclosed by pelitic gneiss. ACD: 1988.

A. L. HOERSCH, LaSalle Univ., and W. A. CRAWFORD, Bryn Mawr Coll. **The Mine Ridge of the S.E. Pennsylvania Piedmont.** A manuscript is in the final stages of preparation. We have used whole rock, major-element geochemistry to aid in suggesting protoliths for the crystalline rocks, mineral assemblages to unravel metamorphic history, and gravity/aeromagnetic data to allow speculation on the thickness of the crystalline rocks. ACD: Summer 1987.

Mineralogy

C. B. SCLAR, Lehigh Univ. **Mineralogy of Radioactive Occurrences Along Bushkill Creek, Northampton County, Pa.** The serpentinized marble containing abundant "eastonite" mica on the *west* side of Bushkill Creek also contains disseminated uranian thorianite. This is the westward extension of Chestnut Hill. Associated with the thorianite is a red-brown to dark-brown, fine-grained secondary thorium and uranium mineral which, on preliminary examination, appears to be a member of the zippeite group. These minerals are the source of the high radon readings in this area. ACD: Oct. 1987.

Paleontology

D. K. BREZINSKI, Md. Geol. Survey. **Appalachian Carboniferous Trilobites.** The stratigraphic and paleoecologic distribution of Pennsylvanian and Mississippian trilobites from eastern Ohio, southwestern Pennsylvania, northern West Virginia, and western Maryland is being compiled. ACD: Dec. 1987.

D. K. BREZINSKI, Md. Geol. Survey, and H. B. ROLLINS, Univ. of Pittsburgh. **Reinterpretation of Crinoid-Platyceratid Interaction.** Study of crinoid stands and attached platyceratid gastropods from the Wymps Gap Limestone of southwestern Pennsylvania has provided evidence for the reinterpretation of this association. ACD: June 1987.

G. R. McGHEE, Rutgers Univ., and A. G. WARNE, Univ. of N. C. **Late Devonian Biostratigraphy and Marine Ecology** [Allegheny Front]. ACD: Ongoing.

W. A. OLIVER, JR., U.S. Geol. Survey. **Corals and Biostratigraphy of the Keyser and Helderberg Limestones and Equivalents in the Appalachian Basin** [N. Y., N. J., Pa., Md., W. Va., Va.]. Rugose corals are being described, and their stratigraphic and areal distribution analyzed, from the fine-grained, stromatoporoidal facies of Pridolian-Lochkovian age. ACD: 1988.

PAUL STROTHER, Boston Univ. **Early Terrestrial Plant Remains from Pennsylvania.** Carbonized compressions of *Nematothallus* are preserved in a coaly horizon found in the Bloomsburg Formation at Port Clinton, Pa. To date, three new species of this problematic thallus have been ascertained. These remains represent plantlike organisms from terrestrial ecosystems that occurred prior to the rise of the vascular plants. ACD: 1987–95.

J. F. TAYLOR, Ind. Univ. of Pa., R. J. CUFFEY, Pa. State Univ., and K. R. CERCONE, Ind. Univ. of Pa. **Characteristics of a Late Silurian Bryozoan-Coral-Stromatoporoid Patch Reef in the Byers Island Member of the Keyser Formation, Altoona, PA.** A 3- by 10-m patch reef with foliaceous bryozoan-dominated core displays distinct facies representing stages of faunal succession; isotope analyses being undertaken should document whether emergence occurred. ACD: 1988.

J. F. TAYLOR, JAMIE MacBLANE, and RICHARD TRAUT, Ind. Univ. of Pa., and JOHN REPETSKI and RANDALL ORNDORFF, U.S. Geol. Survey. **Biostratigraphy of Upper Cambrian and Lower Ordovician Strata in the Central Appalachians.** Trilobite and conodont faunas from the Stonehenge and Conococheague Formations (Nittany Arch/Great Valley) and from the Frederick and Grove Formations (Frederick Valley, Md.) document shoreward (NW) migration of "Stonehenge lithofacies" during Late Cambrian and Early Ordovician time. ACD: Ongoing.

ALFRED TRAVERSE and ANDREW SCHUYLER, Pa. State Univ., J. S. BRIDGE, SUNY, Coll. at Binghamton, and RUDY SLINGERLAND, Pa. State Univ. **Palynostratigraphy and Palynologically-Based Paleoecology of the Catskill Delta (Magnafacies) of New York and Pennsylvania.** Spores from Catskill delta rock of Pennsylvania and New York are being investigated biostratigraphically. The rocks are palynologically late Givetian to early Frasnian in age; refinement is expected. Relationship of spore complexes to sedimentary environments is also being studied. ACD: Ongoing.

C. WNUK, Project Chief, U.S. Geol. Survey. **Paleoecology of Coal and Coal-Bearing Rocks.** The results of preliminary field investigations begun in FY 1985 in the Western Middle Anthracite field (Trevorton, Shamokin, Mt. Carmel, Ashland, Shenandoah, and Delano quadrangles) indicate that plant communities varied significantly in composition and architecture over very short lateral distances. These differences are attributed to local variations in water tables and microenvironmental conditions. The investigations have led to the discovery of a series of previously undocumented community types and a variety of new tree species. ACD: FY 1988.

PAUL ZELL. **Paleontology of the Lower Ordovician Nittany Dolomite in Central Pennsylvania.** ACD: Ongoing.

Sedimentology

EDWARD COTTER, Bucknell Univ. **Medial Silurian Depositional History** [central Pa.].

A. L. GUBER, Pa. State Univ. **Facies Analysis of the Middle and Upper Silurian Formations of Central and Western Pennsylvania.** A geochemical, paleontological, and sedimentological approach to facies definition and analysis of the Mifflintown, Wills Creek, and Tonoloway Formations. ACD: Ongoing.

RUDY SLINGERLAND and JEAN-PIERRE LOULE, Pa. State Univ. **Shallow Marine Sedimentary Processes Along the Upper Devonian Catskill Shoreline in Pennsylvania** [north-central to south-central Pa.]. To better determine the relative contributions of wind- versus tide-driven nearshore flows along the Catskill shoreline, six stratigraphic sections are being measured along depositional strike across Pennsylvania. The first occurrence of clearly continental facies has been chronostratigraphically correlated among sections using palynomorphs. Results show a substantial increase in the thickness of shoreline deposits and quartz-pebble conglomerates to the south. ACD: Sept. 1987.

R. P. STEINEN, Univ. of Conn. **Syntectonic Sedimentation during Late Silurian/Early Devonian—Valley and Ridge** [south-central Pa.]. ACD: Summer 1989.

S. D. WEEDMAN and A. L. GUBER, Pa. State Univ. **Depositional Environment of the Upper Freeport Limestone** [Armstrong and Indiana Cos.]. ACD: Dec. 1987.

DON WOODROW, Hobart and William Smith Colls. **Shoreline Facies in the Catskill Delta, New York and Pennsylvania** [northern Pa. and east-central N. Y.]. ACD: 1987.

Stratigraphy

D. K. BREZINSKI, Md. Geol. Survey, and C. A. KERTIS, U.S. Bur. Mines. **Depositional Environments of Some Lower Mississippian Coals from Western Maryland and South-Central Pennsylvania.** The Rockwell and Burgoon Formations of Pennsylvania and Maryland contain numerous thin coal beds. The purpose of this project is to examine these coal beds with respect to their depositional settings. ACD: Dec. 1987.

JOAN CULLEN-LOLLIS, Univ. of Cincinnati. **Chemical Fingerprinting, Clay Mineralogy and Petrology of Middle Ordovician K-Bentonite Beds in Central and Southeastern Pennsylvania, Maryland and Northern Virginia.** ACD: Dec. 1987.

J. R. EGGLESTON, Project Chief, U.S. Geol. Survey. **Pennsylvania Anthracite Basin Framework.** A fossil assemblage from the #25 coal bed in the Southern Anthracite field was collected in FY 1985 and fossils were identified for stratigraphic purposes. Eleven limestone outcrops were identified and sampled in the Northern Anthracite field near Wilkes-Barre. Paleontologic and petrologic analyses will be performed on these samples in FY 1987–88, as well as additional field work; the lateral extent, character, and depositional history of the Mill Creek Limestone will be defined. In addition, stratigraphic relationships in the Pennsylvanian- and Mississippian-age rocks of the Northern field are being studied. ACD: FY 1989.

T. FLAHERTY III, Univ. of Pittsburgh. [**Upper Devonian Gas-Bearing Sands in Western Pennsylvania.**] Depositional environments will be interpreted based on sand-body geometry as measured from well logs and subsurface drilling samples. ACD: Aug. 1988.

A. D. GLOVER, C. H. DODGE, L. J. LENTZ, J. G. PHILLIPS, J. R. SHAULIS, and V. W. SKEMA, Pa. Geol. Survey. **TASIC (Temporarily Available Stratigraphic Information Collection).** A continuing program to collect stratigraphic data and coal samples for analysis in active coal and clay mines in north-central and western Pennsylvania. The project will provide data for future mapping and regional resource evaluation. ACD: Ongoing.

P. W. GOODWIN and E. J. ANDERSON, Temple Univ. **Punctuated Aggradational Cycles, Upper Silurian-Lower Devonian, Helderberg Group, Central Appalachians** [central Pa., N. Y., Va., W. Va., and Md.]. Documentation, correlation, and paleogeographic analysis of punctuated aggradational cycles in the Silurian-Devonian carbonate sequence, central Appalachians. ACD: 1990.

J. D. INNERS and L. J. LENTZ, Pa. Geol. Survey. **The Mississippian-Pennsylvanian Transition in the Eastern Middle Anthracite Field** [Luzerne, Schuylkill, and Carbon Cos.]. ACD: 1988.

R. C. SMITH, II, Pa. Geol. Survey, J. H. WAY, Lock Haven Univ., and J. H. BARNES and S. W. BERKHEISER, JR., Pa. Geol. Survey. **Bentonite Zones and Time-Stratigraphic Markers in Pennsylvania.** Correlations and fission-track unloading data for the Tioga Ash Zone have been published. Contrary to popular belief, Lower and Middle Devonian lithic units become older to the west. Other Paleozoic and Mesozoic units are being considered for stratigraphic and mineralogic study. ACD: Ongoing.

Structural Geology

PETER GEISER and KARL UHRBACH-MALIM, Univ. of Conn. **Relationship Between the Distribution of Folding Strains and Pressure Solution in Orthoquartzites** [Juniata culmination, Valley and Ridge province]. ACD: Sept. 1988.

M. L. HILL, DAVID VALENTINO, and T. S. SONG, Temple Univ. **Structural Investigations Along the Martic Zone, Southeastern Pennsylvania.**

The Martic Line lies within a major transcurrent shear zone, extending at least from south-central Pennsylvania to Trenton, N. J. A goal of this investigation is to assess displacement across this shear zone. ACD: 1989.

ASSAD IRANPANAH and EDGAR HOPKINS, Univ. of Pittsburgh at Bradford. **Tectonic Analysis of Lineaments Delineated on Landsat Imagery of the Allegheny Plateau in North-Central Pennsylvania and Western New York.** Four major sets of lineaments have been identified, trending approximately 10-20 (NNE), 50-60 (NE), 125-130 (NW), and 160-170 (NNW). Comparison of their orientation with a deformation diagram, and knowledge of the regional structural grain of the basement suggest that most are of late Precambrian age and were formed under the influence of a uniform principal horizontal stress toward the northwest, parallel to the lineament set along that trend. ACD: Aug. 1987.

P. T. LYTTLE and J. B. EPSTEIN, Project Chiefs, U.S. Geol. Survey. **Junction of the Central and Northern Appalachians.** All mapping at a number of sites along the Taconic unconformity in eastern Pennsylvania has been completed. This is part of a larger project, the purpose of which is to study the unconformity from Pennsylvania to southern New York, which includes attempting to determine stratigraphic and structural changes parallel to and across the unconformity, as well as the relative and absolute effects of the Taconic, Acadian, and Alleghanian orogenies on the rock of the Silurian Shawangunk (Tuscarora) and Ordovician Martinsburg Formations. ACD: FY 1988.

R. P. NICKELSEN, Bucknell Univ. **Structural Evolution of Northwest Limbs of 1st Order Anticlinoria in the Valley and Ridge Province.** [Burnt Cabins, McConnellsburg, Meadow Grounds, Big Cove Tannery, Spruce Creek, Williamsburg, Frankstown, Bellwood, Butler Knob, Saltillo, and Orbisonia quads.].

L. B. PLATT, Bryn Mawr Coll., and D. H. Harrison, Ariz. State Univ. **Compressive Strain in Lower Mesozoic Rocks in Southeastern Pennsylvania.** ACD: 1987.

T. S. SONG and M. L. HILL, Temple Univ. **The Origin and Implications of a Steep Gradient in Gravity Anomalies in the Vicinity of the Martic Zone, Southeastern Pennsylvania.** Gravity anomalies are compared with rock density, topographic relief, and expected crustal thickness to determine the most likely origin of the steep gradient in gravity anomalies which coincides with the Martic Zone. ACD: Dec. 1987.

D. W. VALENTINO, Temple Univ. **The Orientation and Structural History of High Temperature Plastic Deformation Along the Rosemont Shear Zone in Del. Co., S.E. PA.** The dominant deformation along the mapped Rosemont fault was due to transcurrent ductile shearing, not faulting. The determination of the boundaries and sense of motion of the Rosemont shear zone is the primary goal of this study. ACD: Oct. 1987.

D. W. WATSON, Slippery Rock Univ. **Study and Interpretation of Joints in the Pottsville Sandstone of the McConnells Mill Gorge.**

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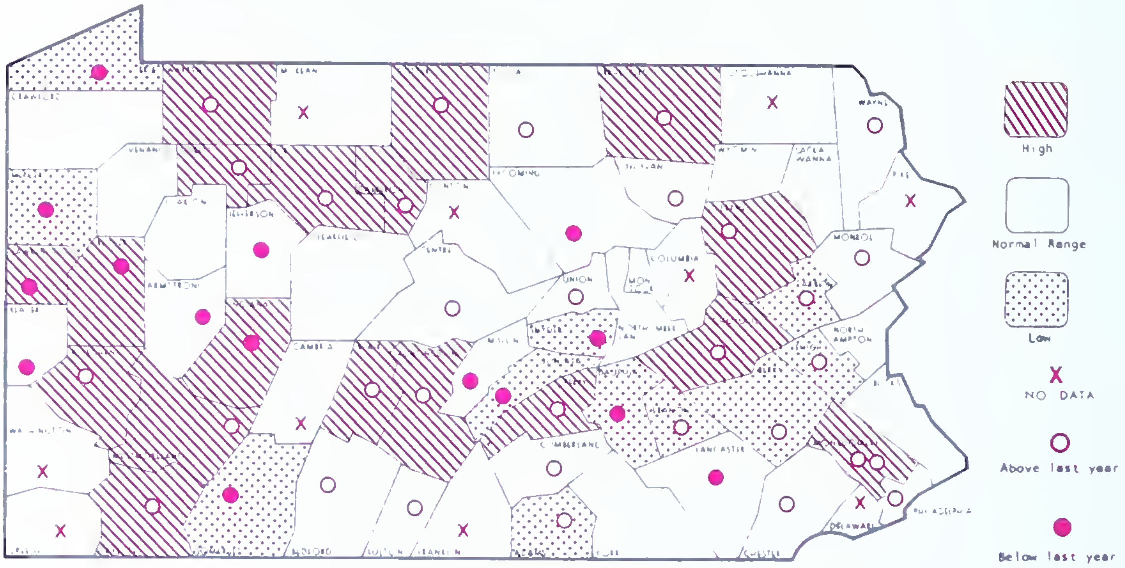

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ON THE COVER: Scanning-electron-microscope (SEM) photomicrograph showing a portion of the void space and pore wall in the Grimsby Sandstone of the Medina Group. (O, quartz overgrowth; c, authigenic iron-rich chlorite rosettes; I, laths of authigenic illite.) The Medina tight reservoirs are the subject of a recent paper by C. D. Laughrey and J. A. Harper of the Pennsylvania Geological Survey (see announcement on p. 15-16). (SEM photomicrograph by Gary Cooke and Feng-Chih Lin of the former Gulf Research and Development Company.)

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Educating for Earth Sense

Most of us possess common sense, the good, sound, ordinary sense that allows us to make daily decisions as to our actions. Common sense is not dependent on any special technical or scientific knowledge. Such is no longer the case for Earth Sense, defined here as the knowledge and appreciation that our daily actions both depend on *and* affect continuously operating natural earth systems. Earth Sense must now be taught because we have successfully insulated ourselves from daily contact with many of these earth systems, such as the processes that produce that lowly product—peat (discussed in this issue), precursor to the abundant coals of the Commonwealth, but mined for itself and annually used in our gardening efforts. How many of us recognize that the baled product available at our local department store's garden shop is the result of complex natural systems?

Earth science and environmental education are once more the concern of educators and scientists in our state and throughout the nation. As reported in our "Earth Science Teachers Corner," a column that will appear more frequently in future issues, a new statement of the importance of educating for earth science (which I trust will lead to a development of Earth Sense) has been prepared.

Our Bureau will contribute to this effort in environmental education through articles in *Pennsylvania Geology*. Pennsylvania's earth science educators can use this issue's article on peat as a resource to teach their students about the natural origin of a Pennsylvania product. Similarly, the article on jellyfish can be used to demonstrate to students that the squishy objects usually seen on a summer's seashore have a very ancient history and a practical use in determining the origin of the rocks in which they are found as fossils. Dinosaurs are not the only fossils that have exciting histories; jellyfish deserve attention, too!

Donald M Hoskins

State Geologist

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DOCUMENTS SECTION

"Mary, Mary, How Does Your Garden Grow?" "With Cockle Shells and Corry Peat, So the Story Goes!"

by Samuel W. Berkheiser, Jr.
Pennsylvania Geological Survey

The old adage "If it does not grow, it is mined" takes on a new meaning with Pennsylvania's peat producers. Perhaps their slogan could be "It is mined to grow better," reflecting the horticultural value of one of the State's more unique extractive industries. According to Davis (1987), there were seven peat producers in Pennsylvania in 1985 collectively mining 20,000 short tons of air-dried peat, mostly in bulk, for the general soil-improvement, potting-soil, nursery, and golf-course markets. Of these producers, five are in northeastern Pennsylvania in Lackawanna, Luzerne, and Monroe Counties and two are in northwestern Pennsylvania in Erie and Lawrence Counties.

Corry Peat Products, located about 1.5 miles northwest of Corry, in Erie County, is one of two producers in western Pennsylvania and typifies the industry in the Commonwealth. Here, Corry Peat mines and processes about 4,000 cubic yards of peat annually from the "Corry Bog." Most of this humus and reed-sedge peat is blended with other media (such as topsoil and sand) to produce custom bulk horticultural blends.

GEOLOGY. The approximately 60-acre Corry Bog formed in a closed depression at an elevation of about 1,450 feet on top of Wisconsinan-age glacial drift. This drift was mapped by White and others (1969) as Lavery Till. Underlying bedrock consists of light-gray to bluish shale, siltstone, and sandstone of the Devonian-age Venango Formation. Bogs usually represent the final cycle or stage in the environmental history of a pond or small lake. Typically, bog stratigraphy in Pennsylvania, as described by Cameron (1970a), consists of glacial drift at the bottom, overlain by a gray clay which was deposited in the pond stage after the glaciers melted. This clay, in turn, is overlain by layers of organic material such as peaty clay, clayey peat, and reed-sedge peat, which represent the marsh stage of peat deposit development. During the last or forest stage, trees infringe upon the marsh and finally take over. This results in a reed-sedge peat (Figure 1A) usually containing branches (Figure 1B), logs, stumps, and sphagnum moss in the upper part. An uppermost layer of decomposed peat, muck, or humus (Figure 1C) is produced by

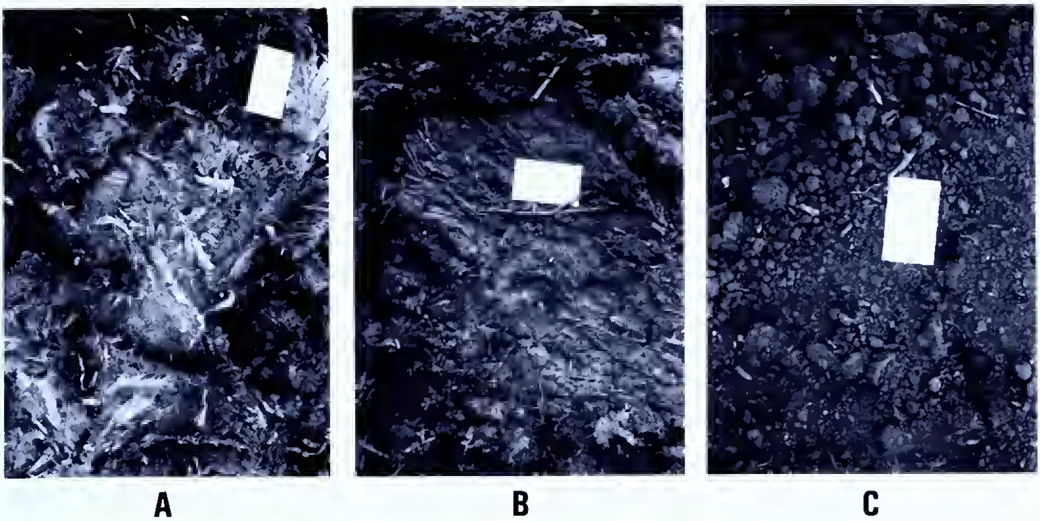

Figure 1. Various types of peat. Card for scale is about 3.5 inches (8.5 cm) long. A. Reed-sedge peat. B. Woody peat. C. Oxidized peat on drying pad, similar in texture to humus.

weathering of the reed-sedge peat, during which aerobic bacteria in the zone above the water table break down leaf and stem structures. Flooding can cause repetition of any stage in this commonly cyclic stratigraphy. From a peat miner's point of view, flooding also introduces clay, silt, and sand that decreases the valuable organic content of peat. Humidity is the critical climatic factor in peat accumulation; it promotes plant growth and facilitates a wet environment in which more peat can form than is destroyed.

Between 20 and 30 feet of reed-sedge and minor humus peat have accumulated in the deepest part of the Corry Bog (Cameron, 1970b; Karrow and others, 1984). The Corry peat contains 65 to 95 percent organic material, has a pH of 5.5, and has an absorption percent of 500 to 600 (Cameron, 1970b). Newly excavated peat is pale yellowish orange and turns to the familiar brownish black only after being exposed for about 15 minutes to the surface (oxidation). Clayey and silty layers are prevalent and closer to the surface on the western periphery of the bog near Bear Creek inlet (Dennis Roth, personal communication, 1986). Branches and twigs with teeth marks from ancestral beavers are common in the woody portions of the deposit. Controversy surrounds the age of the initial pond-stage sediments and of the peat (Cotter and others, 1985; Karrow and others, 1984, 1986). It seems reasonable that the last glaciers retreated from this area at least 14,000 years ago, and that peat accumulation began about 11,000 years ago.

MINING AND MARKETING. Figure 2 illustrates the present mining system used at Corry Peat Products as they near economic depletion. Salient activities include excavating previous haul roads, transporting excavated peat to drying pads (above the 100-year-flood stage), and dragging the drying pads in summer 1 or 2 times per day with a spring-tooth harrow. Two months of summer drying is usually sufficient to remove excess moisture from the newly mined and oxidized peat. The 2- to 3-foot-high windrows and piles of peat are initially smoothed by unusual vehicles, manufactured in Canada, that are designed such that their weight is spread over a wide track, yielding a low number of pounds per square inch of pressure on the ground.

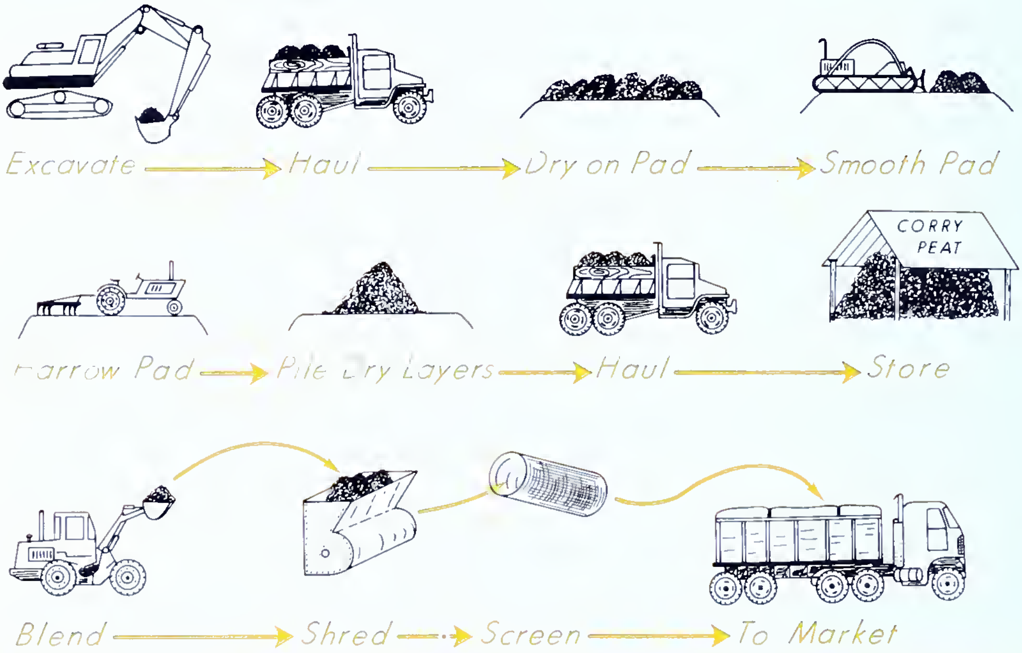

Figure 2. **Schematic diagram of the mining and processing system in use at Corry Peat Products, Corry, Pennsylvania.**

Most of the Corry Bog has been mined to a depth of about 4 feet below the water table. Soil mixes are blended on demand by the scoop method. For example, if a 2–1–2 mix (2 scoops of peat, 1 scoop of topsoil, and 2 scoops of sand) is desired, a front-end loader feeds the proper blend into the chain shredder. The company's steadiest customers are about 100 golf courses which have use for various peat blends as top dressings and plugs for greens, and greenhouses which use various blends as growing media.

The author thanks Dennis Roth, President, Corry Peat Products, for his time and cooperation in helping to prepare this article.

Cornelia C. Cameron of the U.S. Geological Survey critically reviewed the paper and made many valuable contributions, especially with respect to the geology of peat bogs.

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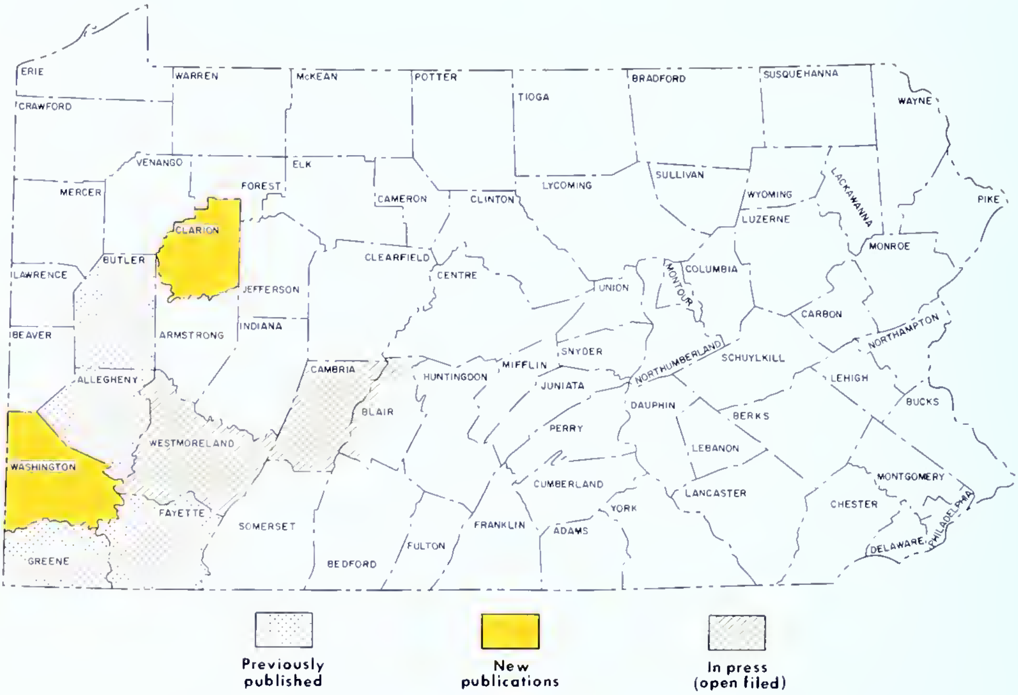
NEW SURVEY PUBLICATIONS

COUNTY COAL RESOURCE REPORTS

The Pennsylvania Geological Survey has released for sale two new county coal resource reports. These reports, compiled by staff geologists Albert D. Glover (Mineral Resource Report 92, Clarion County) and Viktoras W. Skema (Mineral Resource Report 93, Washington County), are two more in a series to be published over the next few years for each of the major bituminous-coal-producing counties in western Pennsylvania. The new coal resource reports contain maps showing coal crop lines, areas of surface and deep mining, and structure contours.

For each of the principal coal seams in each 7½-minute quadrangle there is a map showing the coal outcrop (crop line) and the extent of all known strip and deep mining up to the time of compilation. In addition, for each quadrangle, there is a composite coal crop map that includes structure contours and fold axes. If none of the principal coals have been mined or crop out in a particular quadrangle, only the composite is included.



The two-color maps contain information on sources of published and unpublished data, map reliability, map symbols, map scale (approximately 1:62,500), structure-contour intervals and datums, and names of fold axes. Each report is published as a package of 8½- by 11-inch, pre-punched sheets that will fit standard three-ring binders for convenient use in the office or field.

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NEW OPEN-FILE REPORTS

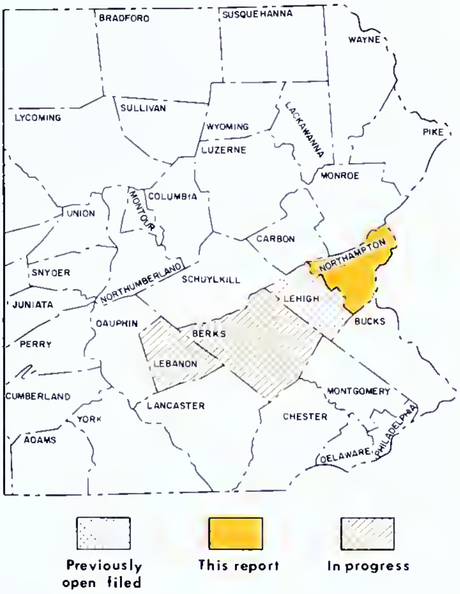
SINKHOLES IN NORTHAMPTON COUNTY

The Pennsylvania Geological Survey has recently released Open-File Report 87-02, **Sinkholes and Related Karst Features of Northampton County, Pennsylvania**. The report, compiled by staff geologist William E. Kochanov, is part of a new series of open-file reports dealing with sinkhole occurrence and distribution throughout all of the limestone regions of Pennsylvania.

This report consists of nine 7½-minute topographic quadrangle maps (scale 1:24,000) and a brief text. The maps depict known sinkhole occurrences, contacts of carbonate bedrock formations, structural data, past and present surface-mine locations, caves, and other karst-related features having surface expression. The text contains a brief discussion of the methods used in compiling the report, definitions of some basic terms pertaining to karst geology, and a list of references on the carbonate geology of Northampton County.

Concurrent with this report, a comprehensive computer data base on sinkholes in Pennsylvania is being developed at the Survey. Mapped sinkhole locations and physical data pertaining to specific sinkholes in Northampton County have been entered into the data base by county, township, quadrangle (7½-minute), and coordinates (latitude and longitude). The data base will be continuously updated and utilized in answering requests for information on sinkholes in Northampton County and eventually throughout the Commonwealth.

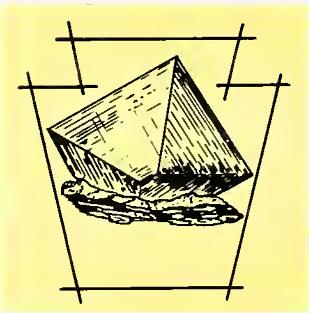
The Northampton County open-file report can be examined at the offices of the Pennsylvania Geological Survey, 9th Floor, Executive House, 101 South Second Street, Harrisburg, or copies of the report can be purchased by mail order at the prepaid copying and shipping cost of $15.00 from the Pennsylvania Geological Survey, Department of Environmental Resources, P. O. Box 2357, Harrisburg, PA 17120. Checks should be made payable to *Commonwealth of Pennsylvania*.



OPEN-FILE COUNTY COAL RESOURCE MAPS

The Pennsylvania Geological Survey has released to open file two new county coal resource reports (see map on page 6). These reports, compiled by staff geologists Albert D. Glover (Cambria and Blair Counties) and Viktoras W. Skema (Westmoreland County), include maps showing coal crop lines, strip and deep mines, and structure contours. The reports have been reviewed and are currently being drafted for publication. They have been placed on open file in order to make them available to the public for examination in the Survey offices in Harrisburg. As open-file reports, the maps are copyrighted and may not be republished, distributed, or sold in any form.

Advance notice of a visit to the Survey offices for the purpose of examining these reports must be given so that drafting or staff schedules will not be disrupted.



EARTH SCIENCE TEACHERS' CORNER

by Andrew J. Verdon, Jr., Director of Education, American Geological Institute, National Center for Earth Science Education, Alexandria, Virginia

I have many fond memories of the years I spent in the secondary school classroom as an earth science teacher. The best memory, though, is the year in which the decision was made to include the "honors freshman" among those students who were required to take a course in earth science. I had finally convinced the administration that it was a course worthy of study by the best and brightest. No longer did they skip directly to the more "important sciences."

I believe we can support our science if school administrators and others are better informed regarding the benefits of a course of study in the earth sciences.

It is to this end that the following statement was created through the cooperation of representatives of many professional societies including the National Science Teachers Association, the National Association of Geology Teachers, the Council of Elementary Science

International, the American Geological Institute, and through much good work of the National Earth Science Teachers Association which coordinated the effort.

THE IMPORTANCE OF EARTH SCIENCE EDUCATION, K-12

Earth science plays a unique and essential role in today's rapidly changing world. It is an integrated study of the earth's history, composition, and structure, its atmosphere and oceans, and its environment in space. A knowledge of earth science is important because most human activities are related to interaction with the planet Earth. Basic knowledge about the earth, then, is the key to development of an informed citizenry.

The reasons for teaching earth science are numerous: it offers experience in a diverse range of interrelated scientific disciplines; it is closely related to the students' natural surroundings; and it offers students subject matter which has direct application to their lives and the world around them. They need only step outdoors to observe and find relevance in concepts learned in their earth science classroom.

Because it offers many opportunities to collect data, hypothesize, experiment, and draw conclusions, both within school and in outside environments, earth science is a laboratory- and activity-oriented course. Earth science integrates many principles of both physical and life sciences. It incorporates and presents concepts often not emphasized in other parts of the science curriculum, such as geologic time and the vastness of space. The teaching of earth science allows all students to have a better science background with pertinent information about their surroundings.

Daily, society is faced with environmental and economic concerns such as acid rain, water supply, the greenhouse effect, and waste disposal. Civilization is absolutely dependent upon utilization of the earth's energy, mineral, and human resources. Awareness of natural phenomena such as floods, tornadoes, hurricanes, volcanoes, and earthquakes also requires a knowledge of earth science. Students who study earth science are better prepared to discuss issues and make informed, responsible decisions.

The interdisciplinary curriculum of earth science develops and builds on skills learned in earlier grades and closely relates to the students' everyday experiences. It develops attitudes and problem-solving skills that will be useful throughout life. If tomorrow's adults are to make wise decisions about earth and environmental issues, it is vital that today's students be given the opportunity to study earth science at all levels as an integral part of their education as well as an invaluable part of their high school experience.

Probable Jellyfish Fossils from Middle Pennsylvanian Strata in Somerset County, Pennsylvania

by James R. Shaulis, Pennsylvania Geological Survey, and
Roger J. Cuffey, The Pennsylvania State University

INTRODUCTION

In 1971, during road construction for a surface coal mine in southwestern Pennsylvania, some large immovable boulders marked by "fossil dog tracks" were encountered. The road was detoured around the rocks so that these fossils could be studied; they appear to be molds of jellyfish stranded on an ancient beach.

Jellyfish preserved anywhere in the fossil record are exceedingly rare; hence it is important that this occurrence be reported. The majority of previously known fossil jellyfish have been obtained from

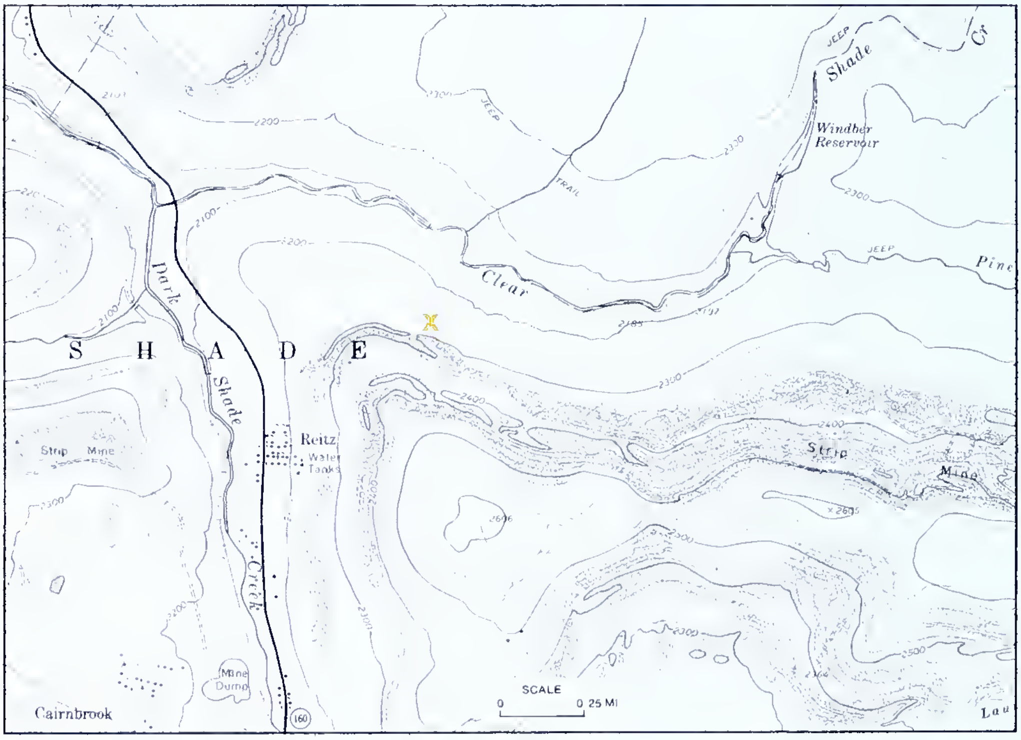


Figure 1. Location of the Reitz jellyfish occurrence (X). Base from U.S. Geological Survey Windber 7½-minute topographic quadrangle.

the Middle Cambrian of Alabama (Walcott, 1896). A few others have been recovered from Precambrian, Devonian, Pennsylvanian, Jurassic, and Cretaceous rocks around the world (Caster, 1945; Chamberlain, 1971; Glaessner, 1971; Haeckel, 1869; Harrington and Moore, 1955; Ossian, 1973; Ulrich, 1893; Wade, 1968). Until now, none have been found in Pennsylvania.

LOCATION, HORIZON, AND LITHOLOGY

The jellyfish site is 0.5 mile (0.8 km) northeast of Reitz, Somerset County, Pennsylvania, in the Windber 7½-minute quadrangle, latitude 40°08′36″, longitude 78°48′10″ (Figure 1).

Stratigraphically, the jellyfish fossils occur 20 to 30 feet (6 to 9 m) below the Lower Kittanning coal (Figure 2). They are in the upper portion of the Kittanning sandstone member (Allegheny Formation, Middle Pennsylvanian). This horizon may be correlative with the marine Vanport Limestone further west (Flint, 1965; Shaffner, 1958; V. W. Skema, 1981, personal communication). It seems reasonable to interpret this sandstone as a beach facies of that marine incursion.

The sandstone in which the jellyfish molds are found is massive, not crossbedded, and occurs as room-sized float blocks, which are 5 to 10 feet (1.5 to 3 m) thick. It consists of 100 percent quartz (as

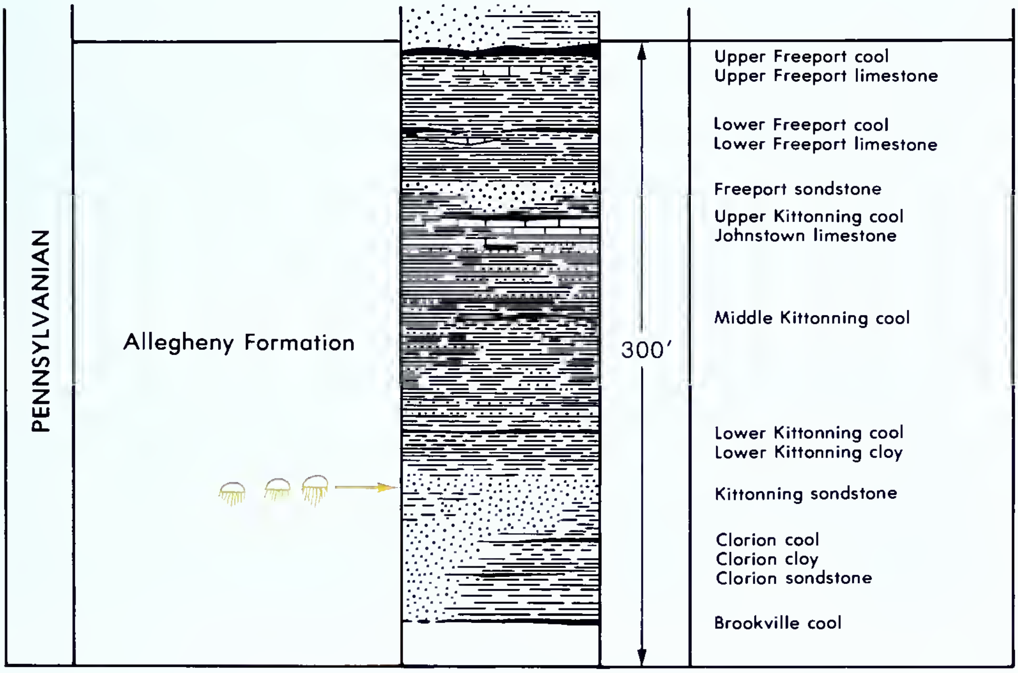


Figure 2. Stratigraphic column (slightly modified from Richardson, 1934) showing the horizon of the Reitz fossil jellyfish.

determined by X-ray analysis), is coarse grained (grain diameter is 0.5 to 1.0 mm and averages 0.78 mm) and well sorted, has very well rounded to oblate grains, and is firmly cemented with silica. The bedding surface on which the jellyfish molds are found varies from flat to gently convex.

PRESERVATION

Due to the coarse-grained nature of the sandstone in which the fossils were formed, only the impressions of the primary and smaller supplementary lobes of the subumbrella or ventral surface of the jellyfish have been preserved. The more delicate subumbrella features such as the tentacles, central mouth, and margin of the gelatinous bell, have been lost. The specimens (Figure 3) are all preserved in the same orientation—subumbrella down and exumbrella up.

Near Reitz, 150 specimens were counted, averaging 1 to 4 specimens per square foot (0.1 m^2) on the bedding surface. Some of the jellyfish molds are infilled with a brown limonitic material that does not extend above the bedding surface nor outside the mold boundary. In thin section, the limonitic material is a thin coating on the quartz grains within a millimeter of the mold surface; the quartz cement overgrowths do not penetrate it. Therefore, the limonitic infilling is a secondary, diagenetic feature.

Observations of modern jellyfish being washed up on beaches (Thiel, 1971, and personal field data of the authors), as well as experimental studies (Wade, 1968), indicate that the orientation of the Reitz specimens is that expected when jellyfish become stranded in shallow water. This further supports the interpretation that these fossils represent a stranding on a beach.

MORPHOLOGY, AFFINITIES, AND IDENTIFICATION

The fossil jellyfish molds are highly variable, circular to elliptical in outline, each a shallow, rounded depression divided into radiating swollen lobes separated by deep grooves. They range from 35 to 58 mm in diameter, and average 10 mm in thickness. Many specimens possess smaller supplementary lobes intercalated between the larger principal lobes. The larger lobes radiate out from a central point, and display a three-, four-, or five-fold symmetry. The deep, thin grooves separating the large lobes in some specimens meet to form an elevated mound in the center; however, it is more common for this elevated central area to be distorted by overlapping supplementary lobes.

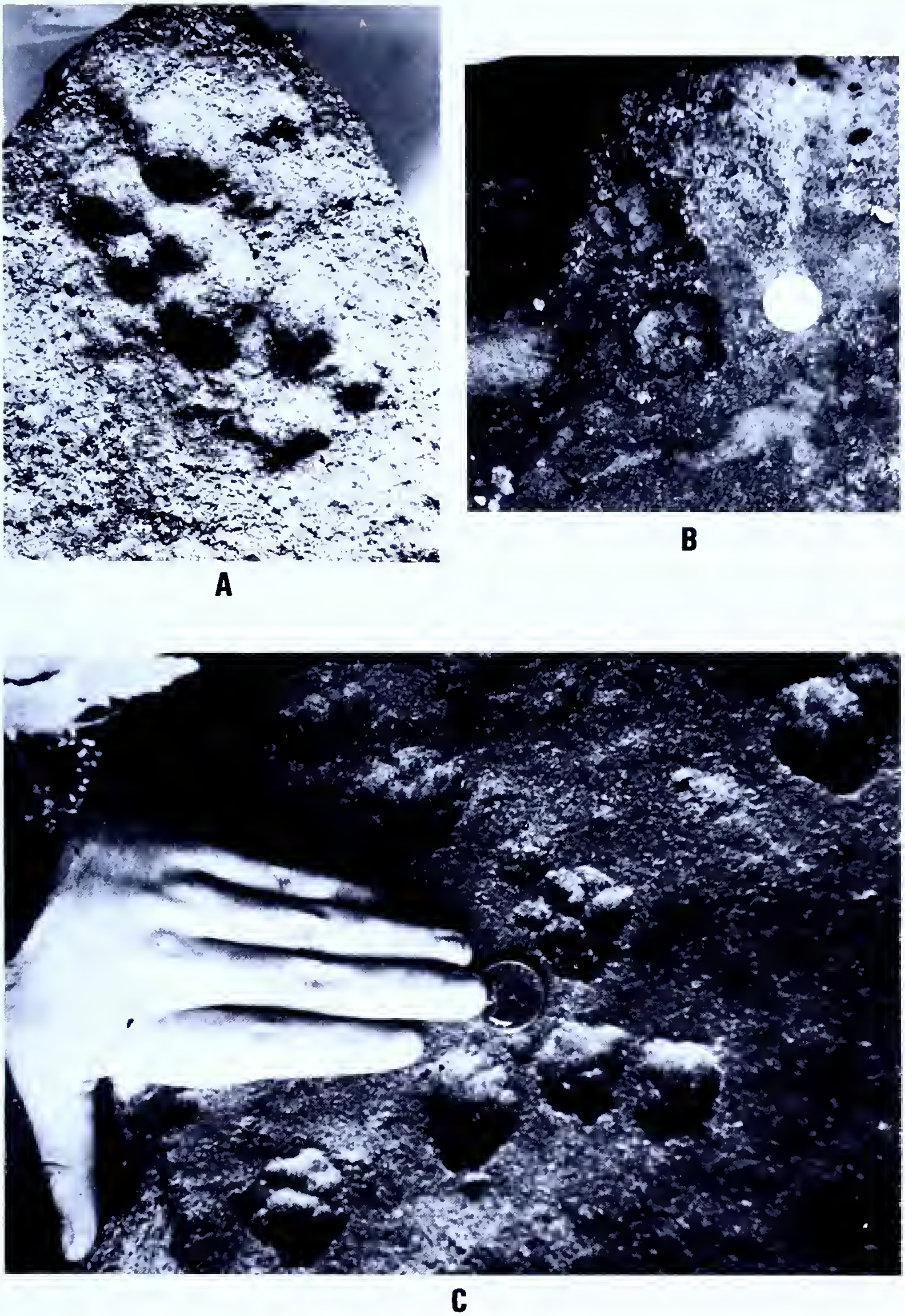


Figure 3. Reitz jellyfish fossils from specimens still in the field. The field of view in A is 100 mm wide; the coins in B and C are 24 mm in diameter.

The Reitz specimens are identified as being of medusoid origin because of their similarity to other fossils previously described as medusae, and their similarity to plaster molds made from present-day medusae. Furthermore, they do not closely resemble any inorganic pseudofossils or any described trace fossils.

Jellyfish described as *Laotira cambria* (Harrington and Moore, 1956, p. F22–F23; Walcott, 1896) are similar enough to the Reitz specimens to warrant referring them to the same genus, but are different enough not to be identifiable as that species. Harrington and Moore (1956, p. F23) synonymize *Laotira* with *Brooksella*. The Reitz specimens do not show sufficiently distinctive morphologic features to provide a basis for description as a new species. Hence, these specimens can be best identified as *Brooksella* sp. indet. (species indeterminate).

Jellyfish, being soft-bodied organisms displaying no hard parts, are seldom preserved in any detail. Usually the delicate outlines and shapes of the fragile body parts are lost or distorted during lithification and diagenesis, and only vague outlines and gross representation of body geometries remain. Because of this, other interpretations of radiating medusoidlike forms should also be considered. Other such fossils have been interpreted as feeding or resting ichnofossils (Grubic, 1970; Häntzschel, 1970; Kauffman and Fursich, 1983; Percival, 1983), or as traces of upwelling gas bubbles (Cloud, 1960). However, the fossils so interpreted differ enough from the Reitz specimens in their morphology that a medusoid interpretation is thought to be more likely.

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AAPG PUBLISHES TIGHT GAS STUDY

Tight gas reservoirs, low-permeability, gas-bearing rocks that occur to some extent in all natural-gas-producing basins worldwide, have been conservatively estimated to have recoverable resources of more than 400 trillion cubic feet of natural gas. Pennsylvania's tight gas reservoirs, including Pennsylvanian coals, Upper and Middle Devonian shales, and Upper Devonian and Lower Silurian sandstones, represent very significant natural resources in the Commonwealth. Gas from the Upper Devonian Venango and Bradford Groups and Lock Haven Formation, and from the Lower Silurian Medina Group, accounts for almost 95 percent of annual production in the Commonwealth. Devonian shales, which have produced gas in Pennsylvania for over 125 years, continue to contribute a small, mostly domestic share to the industry's statistics every year. Investigators have only recently begun to study the potential for natural gas from coals, so the estimations of resource potential still depend in large measure on the particular investigator. These tight reservoirs are important sources of gas and will continue to constitute significant resources in the future.

A recent publication of the American Association of Petroleum Geologists (AAPG), **Geology of Tight Gas Reservoirs,** is the first large volume in which data are assembled on tight reservoirs for an assortment of basins and different geologic settings. This collection of papers, edited by Charles W. Spencer and Richard F. Mast of the U.S. Geological Survey, includes two contributions pertaining to tight gas reservoirs in Pennsylvania.

One of the papers, "Comparisons of Upper Devonian and Lower Silurian Tight Formations in Pennsylvania—Geological and Engineering Characteristics," by Christopher D. Laughrey and John A. Harper of the Pennsylvania Geological Survey's Oil and Gas Geology Division, concerns the similarities between the Upper Devonian (particularly Venango and Bradford) and Lower Silurian (Medina) tight reservoirs. These reservoir sandstones have undergone profound diagenetic alterations, which has produced both positive and negative results. The authors document the importance of secondary porosity and natural fracturing in recovering gas resources from these rocks.

The other paper, "Devonian Gas-Bearing Shales in the Appalachian Basin," by Wallace de Witt of the U.S. Geological Survey, includes a discussion of the development history and a description of the physical characteristics of Devonian gas shales in the eastern United States. The author presents an evaluation of the production potential of 19 plays, including seven that are partially or totally contained in Pennsylvania.

The remaining 12 papers in this collection also have a bearing on the gas reservoirs in Pennsylvania in the sense that the successful exploitation of this resource depends on the development of geologic models and concepts that result in the identification of regions that have optimum-quality reservoirs. These models support technological research into the pragmatic application of artificial stimulation techniques designed to increase productivity and permit economic development.

AAPG Studies in Geology 24, *Geology of Tight Gas Reservoirs* (Catalog: 639), is available from the AAPG Bookstore, P. O. Box 979, Tulsa, Oklahoma 74101-0979, telephone 918-584-2555. The price is $32.00 for AAPG members and $38.00 for nonmembers, plus $5.25 for shipping and handling (in North America). Make checks payable to *AAPG*.

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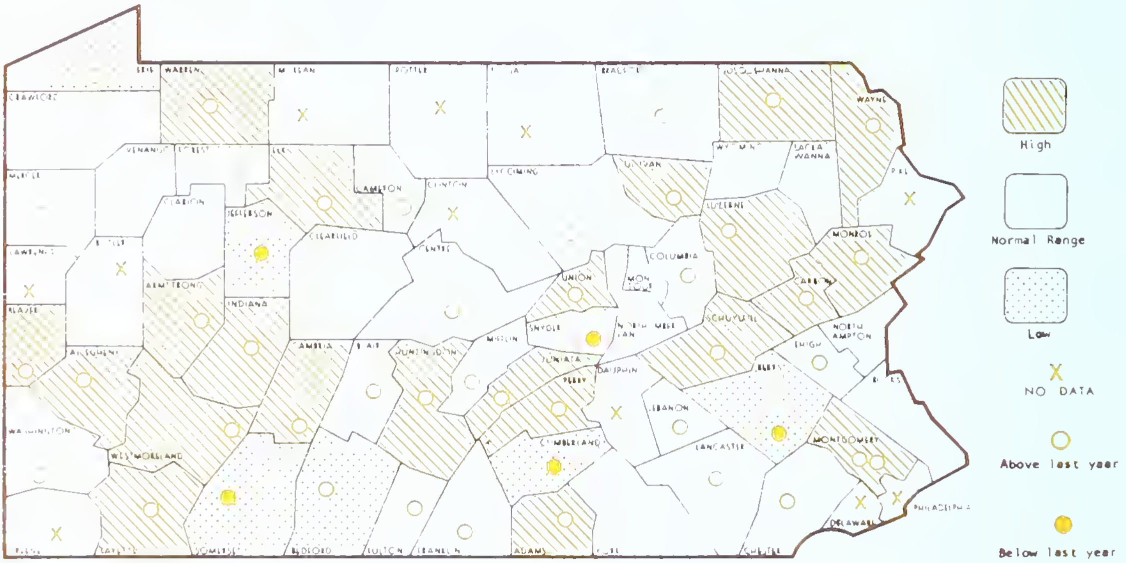

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ON THE COVER: Aerial view of the rockslide on Interstate Route 81 southeast of Nanticoke, Luzerne County, as it appeared on March 21, 1986, one day after cut-slope failure. Note the long headwall scarp and the blocky nature of the slide mass. (Photograph courtesy of the Pennsylvania Department of Transportation.)

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Editor, Christine M. Dodge

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VOL. 18, NO. 6 **DECEMBER 1987**

A River Runs Through It

On occasion come stories that are meant to be shared. Few works of fiction include geology in a way that describes some of the beauty of our science. This is one. Although geology plays only a small part in these stories, those of you who are fishermen, foresters, geologists, or poets, and others who don't mind trees, will enjoy the three stories included in *A River Runs Through It and Other Stories*.

Norman Maclean included under this title two novellas and a short story, which were published by the University of Chicago Press in 1976. These are stories of out-of-doors experiences written so eloquently that geology is a natural part of the main themes of fly fishing, logging, and summer jobs with the U.S. Forest Service. While probing the mysteries of the human players in the stories, Maclean includes much of nature's arts. In his story on the U.S. Forest Service he writes, "You might never have heard the word geology and yet have known the instant you looked down Blodgett Canyon that you were looking at a gigantic, glacial classic. For thousands of years it must have been a monster of ice hissing in the cracks of mountains." Such is the flavor of his writing. These are the stories of a fisherman, philosopher, and poet who understands the geology of the rivers that run through rocks.

Anyone who wishes to learn or relive fly fishing in the great trout rivers of the Continental Divide and to learn of the geologic origins of the rivers, or to know logging in the quiet days before chain saws, or to discover how long is a Forest Service mile when climbing steep trails alone to a fire tower, will need to obtain a copy of this book. For the winter solstice season it is a marvelously good read!

Donald M. Hoskins
State Geologist

The Nanticoke Rockslide of March 20, 1986

by Duane D. Braun, Bloomsburg University, and J. Peter Wilshusen
and Jon D. Inners, Pennsylvania Geological Survey

INTRODUCTION

At 12:15 a.m. on March 20, 1986, a massive rockslide blocked all three southbound lanes of Interstate Route 81 approximately 2 miles southeast of Nanticoke, Luzerne County, northeastern Pennsylvania (Figure 1). The failure occurred in a deep cut on the dip slope of Penobscot Mountain, one of several spectacular rock cuts excavated in the mid-1960's to allow passage of Interstate Route 81 through the southeastern rim of the Wyoming-Lackawanna basin. Because cuts on both northbound and southbound lanes expose rock layers that dip directly into the roadway, this section of Interstate Route 81 had long been suspected of being particularly susceptible to rockslides. For this reason, geotechnical engineers of the Pennsylvania Department of Transportation (PennDOT) had visually monitored its behavior on several occasions. The cuts appeared to be stable, however, and only a few falls of individual rocks took place in the 20 years between construction of the highway and the failure of March 1986.

Luckily, the cut slope in question failed catastrophically at a time of minimal traffic volume on the highway. Although one car—a Corvette—ran up over the rock pile an instant after the slide had stopped moving, no one was injured. By early in the afternoon of the same day, PennDOT maintenance crews had cleared enough of the debris to permit southward traffic flow in the outer two lanes. The third lane was opened several days later.

GEOLOGIC SETTING

The mountainous southeastern rim of the Wyoming-Lackawanna basin in the vicinity of Nanticoke is formed by clastic sedimentary rocks ranging from the Upper Devonian Duncannon Member of the Catskill Formation to the Lower Pennsylvanian Pottsville Formation (Figure 1). Penobscot Mountain, the higher of two northeast-southwest-trending ridges, is underlain by the Duncannon Member on its southeastern, or scarp, slope and the Lower Mississippian Pocono Formation on its northwestern, or dip, slope. The cut-slope failure of March 20, 1986, took place in the latter unit.

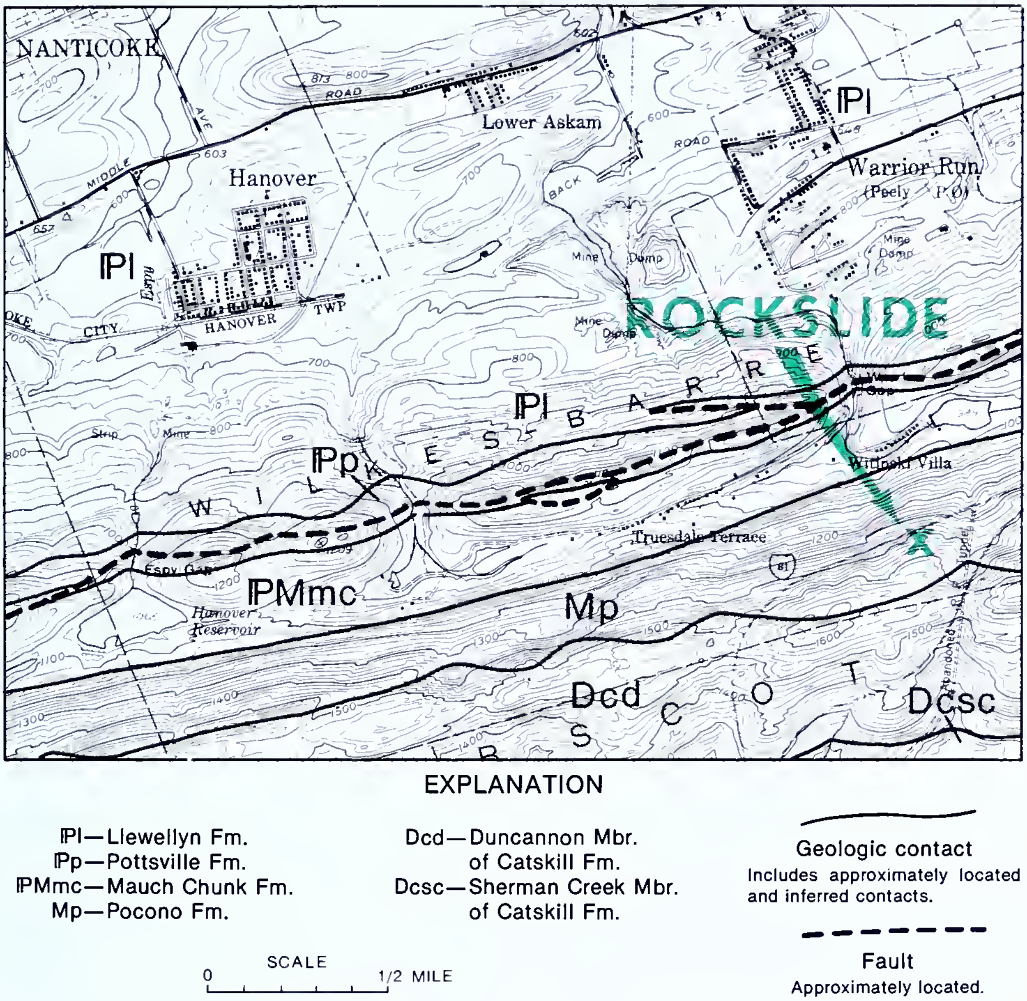

Figure 1. Geologic map of a portion of the Wilkes-Barre West quadrangle, showing the site of the rockslide on Interstate Route 81. Geology after Sevon, in Berg and Dodge (1981), and Bergin (1976).

The Pocono Formation at the site of the rockslide is medium- to thick-bedded (mostly 1- to 2-foot beds), trough-crossbedded, medium-gray, medium- to coarse-grained, micaceous quartzose sandstone, containing thin, discontinuous beds of medium-light-gray mudstone. These rocks represent the deposits of a great braided-river system that developed along the margin of the Appalachian highlands approximately 360 million years ago (Inners, 1978).

Structurally, the site lies on the southeast limb of the Wyoming-Lackawanna synclinorium, a complex, canoe-shaped downfold that contains the numerous anthracite seams of the Northern Anthracite field. Bedding planes dip at moderate angles (30 to 50 degrees) to the northwest, and conspicuous strike and dip joints are mostly subvertical. Spacing of the joints varies from less than 0.5 foot to 10 feet, averaging 1 to 2 feet. The bedding planes and joints are geologic discontinuities which greatly facilitate the percolation of vadose water and the circulation of groundwater through the rock mass.

The area lies 10 to 15 miles northeast of the late Wisconsinan terminal moraine (Crowl and Sevon, 1980) and was last subject to the rigors of continental glaciation about 15,000 years ago. Preserved glacial deposits are very sparse on the mountain slopes, however, and none were observed locally.

THE ROCKSLIDE OF MARCH 20, 1986

At failure, the slide mass was approximately 185 feet wide, 40 feet long, and 20 to 40 feet high and had a total volume of approximately 7,000 cubic yards (see cover). The limiting discontinuities of the failure consisted of a curved, subvertical strike joint (head scarp), subvertical dip joints (side scarps), and several undulatory bedding planes (slide surface) (Figure 2). Shear failure took place mainly within weathered mudstone lenses that partially fill several adjacent northwest-plunging crossbed troughs. At the extreme northeast end, however, slippage occurred on a 1- to 2-inch band of friable sandstone that had been intensely leached and oxidized by the intermittent movement of perched groundwater. The average size of blocks in the slide—1 to 2 feet on a side—reflected the typical spacing of bedding planes and strike and dip joints; one huge block—more than 10 feet square—remained intact at the extreme northeast end (Figure 3).

The trigger for the rockslide may have been two periods of rainfall 5 days (3.1 inches within 24 hours) and 10 hours (0.4 inch within

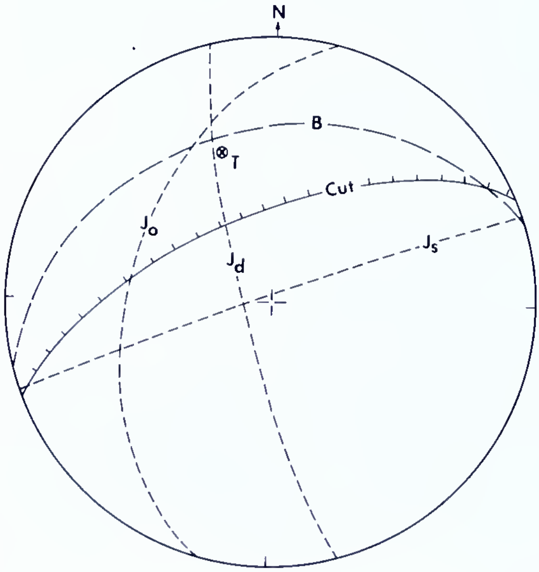

Figure 2. Stereogram (equal-area lower hemisphere projection) of discontinuity planes in the Pocono sandstone at the site of the rockslide on Interstate Route 81. Bedding: B, N73E/35°NW (failure surface). Joints: Js, N70E/89°NW (head scarp); Jd, N15W/82°SW (side scarps); Jo, N15E/46°NW. Axis of crossbed trough: T, N20W at 40°. The cut face shown (N66E at ½ to 1, or 63°) is the design cut slope prior to failure.

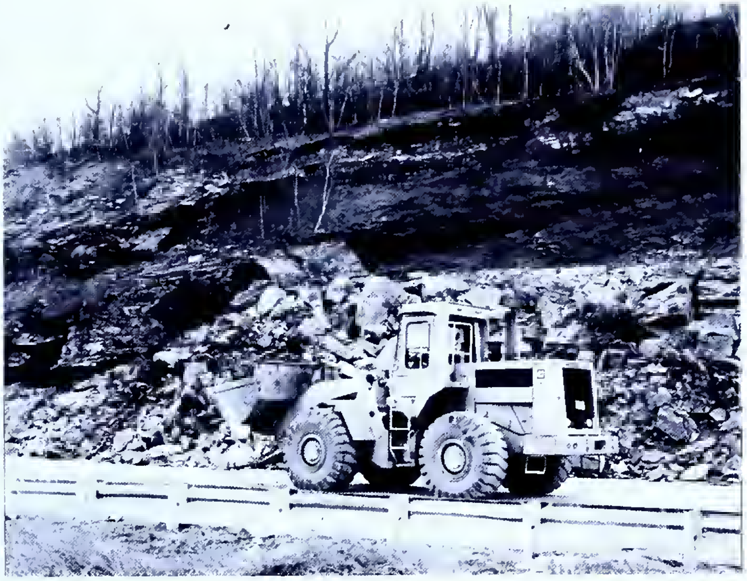

Figure 3. View of the northeast end of the rockslide, showing the large intact block adjacent to the side scarp. Note the subvertical head scarp.

3 hours) before failure (Figure 4; Inners and others, 1987). Excess porewater pressure in the mudstone lenses probably reduced shear strength below a critical level, leading to abrupt slippage. The 5-day

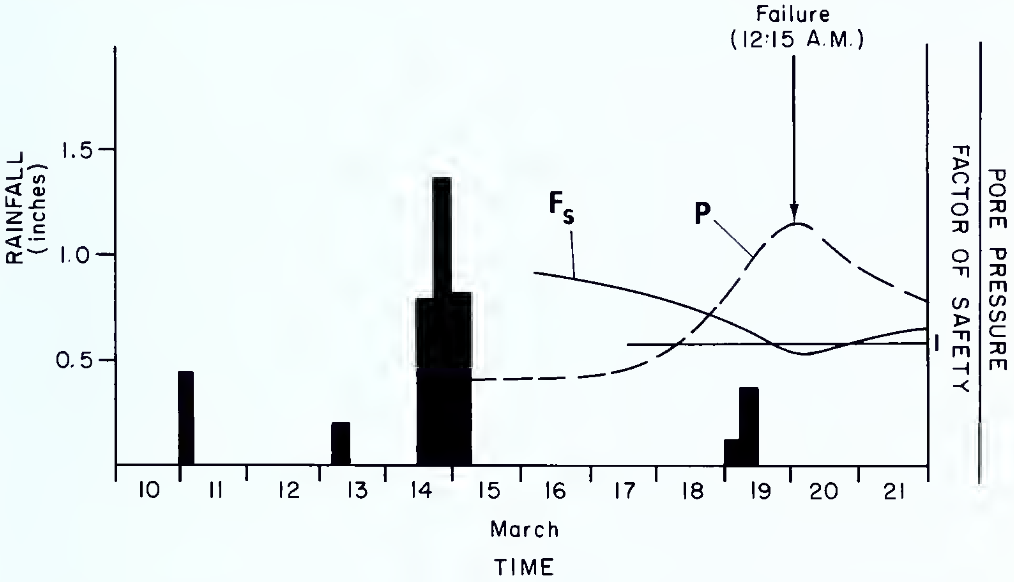

Figure 4. Composite of histogram of rainfall at Wilkes-Barre Scranton airport, Avoca, Pennsylvania, in mid-March 1986 (data from National Oceanic and Atmospheric Administration, 1986) and graphs of the ideal temporal relationship of pore pressure and factor of safety to period of rainfall (from Freeze and Cherry, 1979). Note the lag time between peak rainfall and slope failure at the presumed maximum pore pressure within a slope.

lag between the major rainfall event and failure is apparently related to the time it took for the precipitation to infiltrate from the surface and upslope of the incipient slide and generate maximum pore-water pressure within the potential slide surface and the headwall tension crack (Freeze and Cherry, 1979; see Figure 4). Wilson and Dietrich (1985) observed a similar delayed response (about 4 days) in the maximum pore-water pressures registered in piezometers in an incipient slide mass on a slope in the California Coast Ranges.

But why did the cut slope fail on this particular occasion more than 20 years after construction of the highway? Considering that the shear stress imposed by the weight of the incipient slide mass has been relatively constant since the cut was excavated and that high excess pore-water pressures have probably developed in the slope on many occasions, it seems likely that only a weakening of the bond across the slide surface over time can account for the failure. Both weathering and fatigue could cause critical reductions in strength of the mudstone and sandstone that would lead to slippage of the bedrock wedge off the slope.

Repair of the Nanticoke rockslide caused an extensive traffic detour, took several days of unplanned-for work time, and cost approximately $53,000.

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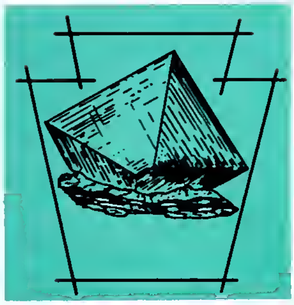

EARTH SCIENCE TEACHERS' CORNER

by The Schoolhouse Mouse

If We Don't Teach Them, Who Will? A New Teaching Resource for the Earth Sciences

One pitfall geologists and miners have historically succumbed to is our reluctance to explain what we do, why we do it, and how it makes life a little easier and safer for the rest of the population. We have had a difficult time with the social and political aspects of extracting mineral resources from the earth's crust.

Fortunately, we have Robert L. Bates, Professor Emeritus at Ohio State University, and, among other things, founder of the annual Forum on the Geology of Industrial Minerals, who has given us tongue-tied professionals books with which we can explain to our children (and curious neighbors) the wonders of the earth's crust and man's ingenuity.

Stone, Clay, Glass—How Building Materials are Found and Used, published by Enslow Publishers, Inc., should be required reading for every intermediate schoolchild in Pennsylvania. In a succinct 60 pages, Bates explains the history, uses, and occurrences of construction materials and their importance in our everyday lives. Although there may be more glamorous mineral commodities, none have played a more significant role in the development of Pennsylvania and the nation. As an example of Bates' humor, skill, and wit, do you know what nummulites and vanity had to do with one of the seven wonders of the world, or how the Romans' thirst for water is related to arches and concrete? Did you know that the quarries that supplied marble for the Parthenon in Greece (Temple of Maidens for you students not yet paying attention) are still in business after 2,000 years, or that a supercooled liquid that we take for granted every day has a case of arrested development but is rich in silica? Do you know

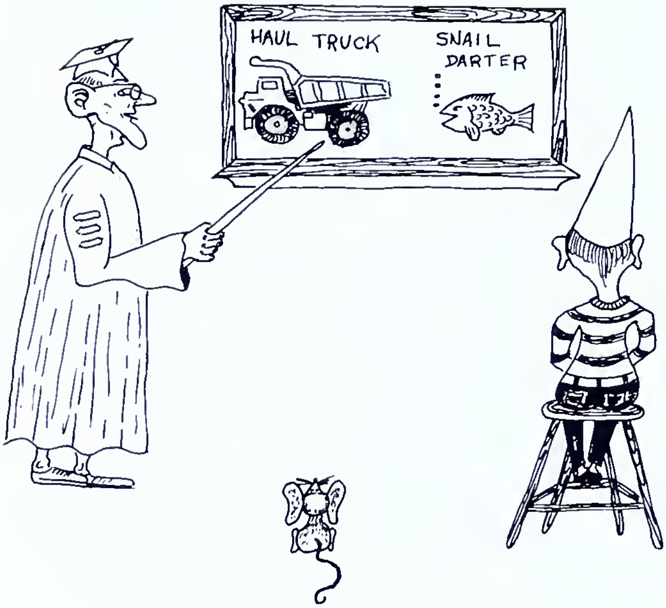

Figure 1. The well-rounded environmental education.

what a plaster sandwich is? What construction material is being used by the chef in the following recipe?

> Take 2 cups crushed limestone; add one-half cup clay or ground-up shale; mix thoroughly and grind fine. Bake in white-hot oven at about 1427°C (2600°F). Cool. Add 1 teaspoon gypsum and grind very fine.

Intermediate-grade science teachers in Pennsylvania will find this book an invaluable teaching aid in the earth science curriculum. Furthermore, Bates' wisdom, gained from many years in the teaching profession, is evident throughout. For example, teachers could find inspiration on what to do with that particularly troublesome student, and every class has one, by creative assignments such as picking out a grain of clay.

Pennsylvania has always been a leading state in the production of industrial minerals as well as building materials; recent values have totaled nearly one billion dollars per year. We should be proud of our mineral heritage and what this industry has accomplished. For those students (young and old) who would like to learn more, we recommend other contributions by Bates and J. A. Jackson such as *Our Modern Stone Age,* published by William Kaufmann, Inc. This well-illustrated book includes such chapters as "Rocks en Route," "The Disassembly Line: Taking Rocks Apart," and "Blast It Out and Break It Up (But Not in My Neighborhood)." A well-rounded environmental education (Figure 1) should include an understanding of our dependence on industrial rocks and minerals and the role of geology and technology in producing them.

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Cumberland County's

BIG SPRING

by Michael W. Smith, Pennsylvania Department of Environmental Resources, Bureau of Mining and Reclamation, and
William E. Kochanov, Pennsylvania Geological Survey

Big Spring, located approximately 3 miles south of Newville in western Cumberland County, is Pennsylvania's fifth largest spring (Flippo, 1974) (Figure 1). Aside from its large volume discharge (from 11,000 to 16,000 gal/min [gallons per minute]), it has unique hydrogeological characteristics and has played an important role in the history and development of Cumberland County.

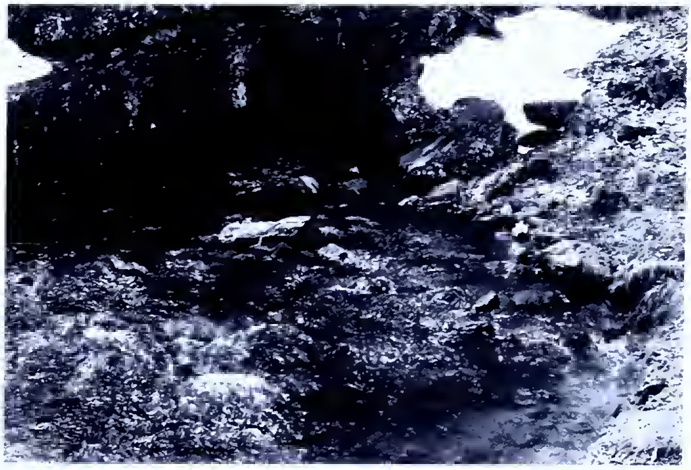

Figure 1. Big Spring (photograph from Geyer and Bolles, 1979).

HISTORY, 1700 TO PRESENT. Indians were numerous along Big Spring when Andrew Ralston settled there in 1728. Around 1733, after both banks of the spring had become populated by Scotch-Irish and German settlers, trouble with the Indians began and continued for many years. In a record dated August 17, 1764, an account was given of a young woman, the daughter of James Dysart, who, while "going home from a sermon at Big Spring last Sunday was met with, murdered and scalped and left naked by the enemy. . ." (Rife, 1965). Despite such hair-raising episodes, most of the land around Big Spring was settled by 1750. This was due in part to the large grants of land that were offered to settlers as an incentive to construct and operate grist mills to supply England's army during the French and Indian War. Thus, the spring took on new importance as a source of power for the mills. With such an interest in the Big Spring area, the town of Springfield, located at the head of Big Spring Creek, was at one time considered as a possible county seat.

Due to the plentiful and relatively constant flow of Big Spring Creek, most of which is provided by Big Spring, six mills were spread out along its length (Figure 2). The McCracken Mill was probably the most important because it was located at the head of the spring and could operate at a much greater capacity. The success of this mill stemmed from an incident in 1877 in which the owners of the mill received an order for 50 barrels of flour from a firm in New York. The order was filled promptly because the flour was going to Queen Victoria of England. To the delight of

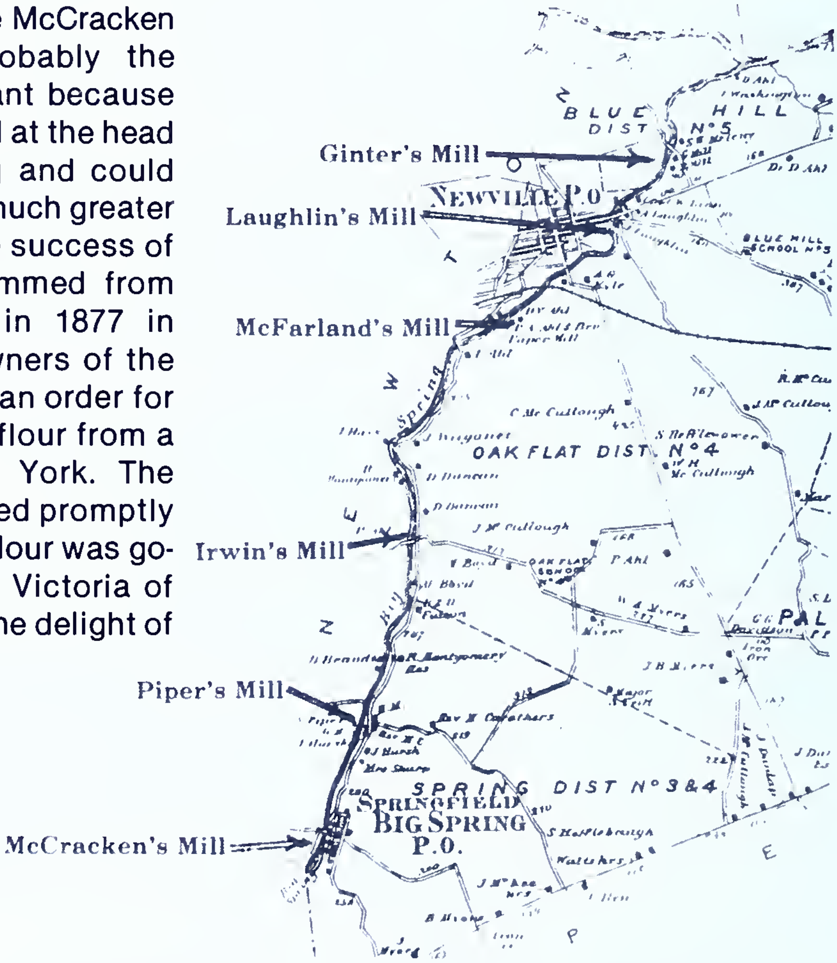

Figure 2. Locations of the mills along Big Spring Creek (base map dated 1872; photographed from 1985 calendar of the Newville Historical Society, Newville, Pa.).

the Manning Brothers, who were operating the mill at that time, Queen Victoria was so pleased with the quality of the flour that she ordered an additional 100 barrels. The enterprising operators took advantage of this bit of good fortune and were soon advertising, "flour good enough for the Queen should be good enough for anybody" (Kressler, 1965).

Throughout their history, the mills along Big Spring produced flour, timber, paper, and knitted goods and were in operation until the 1930's. All of the mills have since been dismantled, leaving behind remnants of mill dams, ponds, and raceways.

Although the spring is no longer used for milling, its water is still an important resource. Currently, the Pennsylvania Fish Commission pumps from 6 to 10 million gallons of water daily from the spring to raise trout at its Big Spring Hatchery. Due to the nearly constant flow and temperature of the spring, which provide excellent conditions for trout, Big Spring Creek is classified as a "limestone spring wild trout water."

HYDROGEOLOGY. Big Spring discharges from the Stoufferstown Formation, a Lower Ordovician limestone of the Beekmantown Group (Figure 3). Becher and Root (1981) studied the hydrogeology of the area and noted that the apparent groundwater drainage area of Big Spring (approximately 5¼ square miles) was far too small to maintain the large discharge from the spring. They also noted that Yellow Breeches Creek and its tributaries, directly south of Big Spring, lose water and usually are dewatered over this section during the summer and fall months and that the water from the spring exhibits lower specific conductance than groundwater from most wells in the area. The most likely explanation for the large flow of Big Spring, they concluded, was that water on the flank of South Mountain, which enters bedrock solution openings through the colluvium along the mountain flank, flows under Yellow Breeches Creek to Big Spring.

To further examine the hydrologic characteristics of Big Spring and to verify Becher and Root's conclusions, the Pennsylvania Geological Survey installed a continuous-recording stream gage at the former McCrackens Mill Dam, approximately 600 feet downstream from the spring, which includes the flow of several smaller springs discharging a short distance downstream from Big Spring. The flow was measured over a period of one year (April 10, 1986, to April 9, 1987). The hydrograph (Figure 4) shows that the spring flow is fairly constant throughout the year, although highest flows of 38 ft^3/s (cubic feet per second) (17,000 gal/min) occurred in April and lowest flows of 25 ft^3/s (11,000 gal/min) occurred in late September and early October. Some response is shown to individual precipitation events, indicating at least some local recharge to the spring, which is probably facilitated by karst features. Because of evapotranspiration losses, summertime precipitation events generally result in less recharge compared to rainfall or snowmelt during the nongrowing season. Periodic temperature and specific-conductance measurements taken by staff of the Pennsylvania Fish Commission also show little fluctuation. Water temperatures varied little from 11 °C except for a rise of 0.5 °C during the summer months and a decrease of 0.5 °C during January and February.

During the year-long measurement period, Big Spring and associated springs had an average discharge of 30.5 ft^3/s. The average recharge rate for the basin of 17 inches per year can only account for approximately 6.6 ft^3/s, given the apparent size of the groundwater basin. A portion of Yellow Breeches Creek south of Big

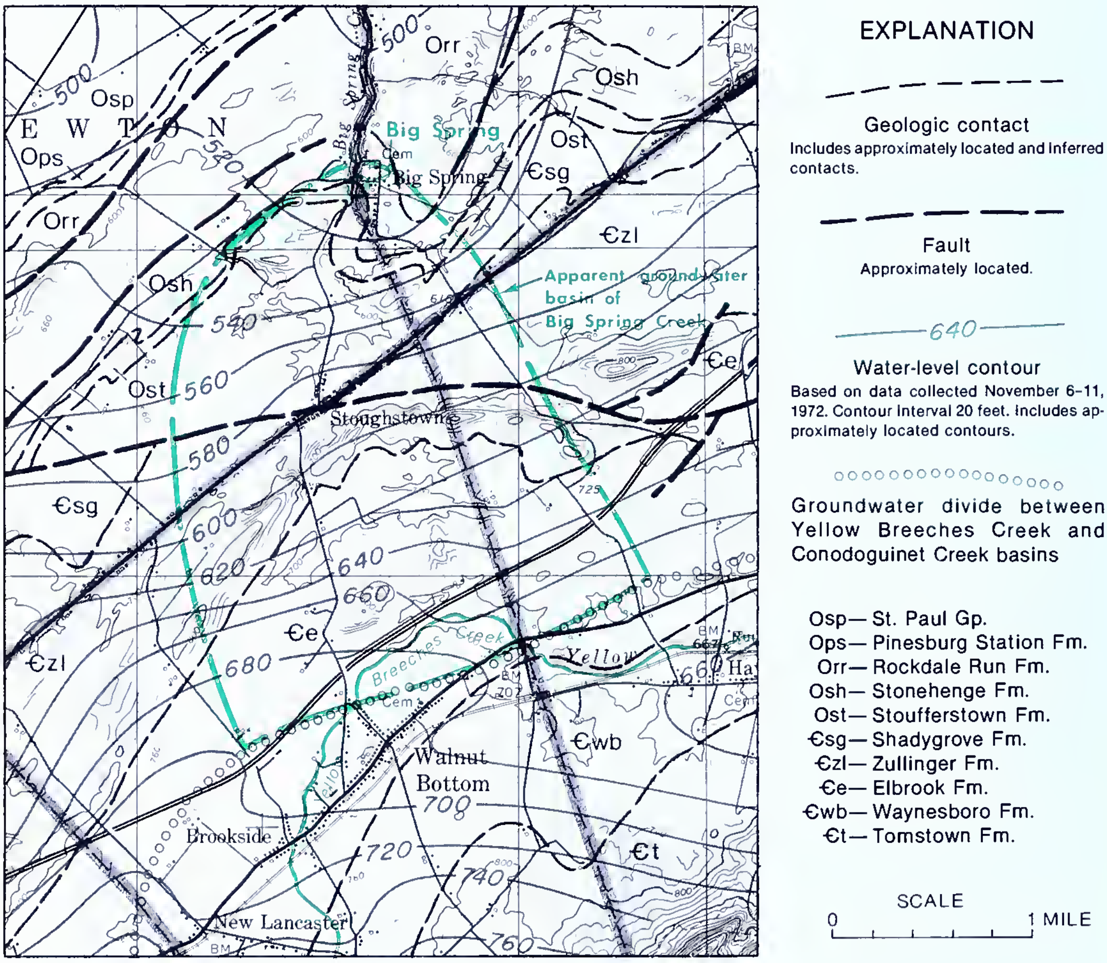

Figure 3. Geologic map of the Big Spring area. Geologic contacts, water-level contours, and groundwater divide from Becher and Root (1981).

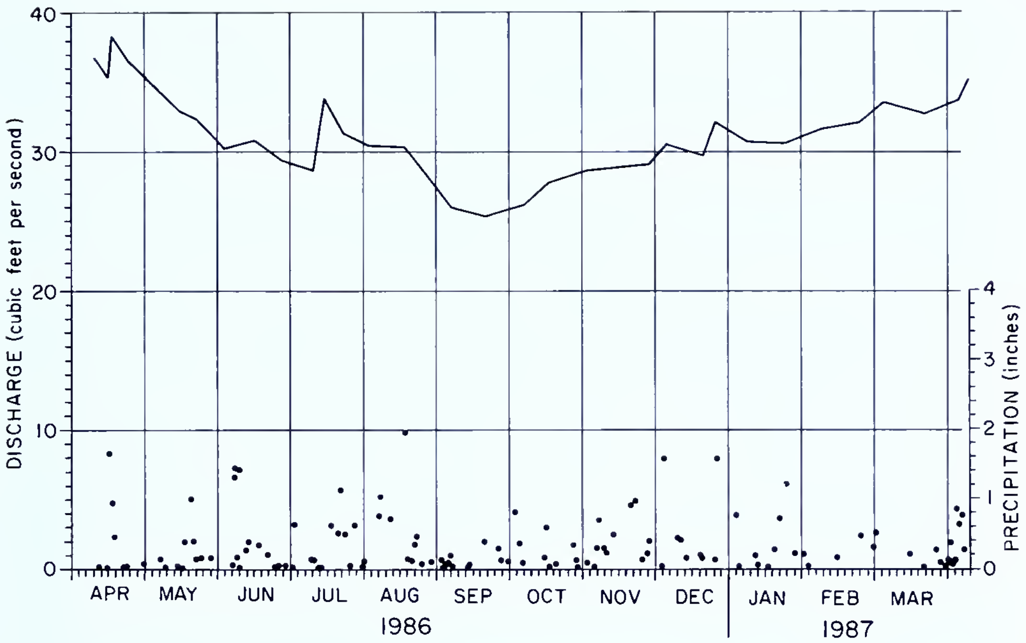

Figure 4. Discharge hydrograph and daily precipitation values at Big Spring for the period April 10, 1986, through April 9, 1987. Precipitation data were supplied by the Pennsylvania Fish Commission.

Spring flows across its own groundwater divide into the Big Spring groundwater basin. Streamflows of Yellow Breeches Creek were measured in this reach of stream, which exhibited losses of approximately 2 ft^3/s, still far less than the quantity that would be required to make up the "extra" flow volume of Big Spring.

It appears, then, that Becher and Root were correct, even though the groundwater flow beneath Yellow Breeches Creek is not manifested in the water-table-elevation contours. Also, a north-south-oriented conduit system may be present which transmits groundwater to the spring. At least one cave, Skelly Cave, that has observable conduit groundwater flow is present near the spring, and additional interconnecting conduits probably exist.

A well-known aspect of carbonate hydrogeology is the difficulty in determining groundwater-flow directions and recharge areas. Through groundwater underflow, Big Spring "steals" water from the Yellow Breeches Creek basin and transfers it to the Conodoguinet Creek basin. As seen with Big Spring, however, groundwater underflow is rarely obvious and can only be detected through extensive geologic and hydrologic investigations.

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Commission, and Georgia Rife of the Newville Historical Society for their assistance and contributions to this article.

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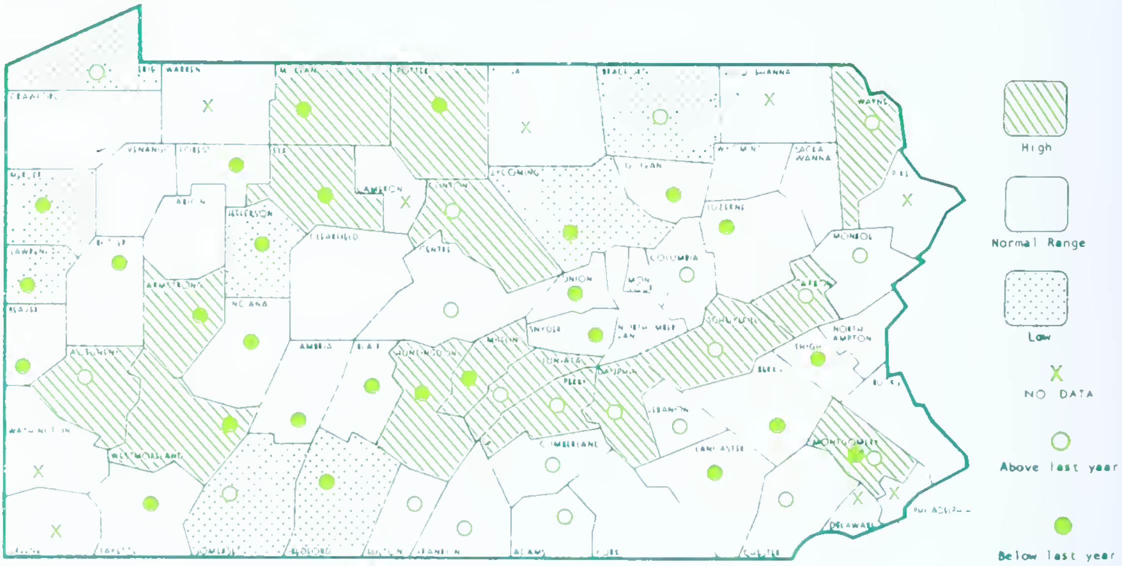

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PENNSYLVANIA GEOLOGY

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THE PENNSYLVANIA GEOLOGICAL SURVEY VOL. 19/1

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TOPOGRAPHIC AND GEOLOGIC SURVEY
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ON THE COVER: Slate of the Pen Argyl Member of the Martinsburg Formation in an exposure near Slatedale, Pennsylvania. This well-known Pennsylvania slate was collected as one of 24 hand specimens included in a new rock set now available for earth science teachers (see article on page 2).

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Editor, Christine M. Dodge

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VOL. 19, NO. 1 **FEBRUARY 1988**

Speak Out! for Geology

In a recent poll of scientists of all disciplines, 22 percent said that **the most important issue facing science today** was a "lack of public understanding of science's place." Another 12 percent said that the public is overreliant on science to provide answers and find solutions (to human problems). Thus over one third of all responding U.S. scientists felt that public understanding of the capabilities and limits of science was faulty.

But is it the fault of the public for not understanding our sciences, in more particular, the scientific geological story that we read in rocks? Or is it the fault of geologists (and all other scientists) who have failed to educate the public about the contribution we can bring to the commonweal?

For too long our science of geology has relied on the natural beauty and myriad colors and shapes of minerals, the complex curiosities that are fossils, whether dinosaurs or ferns, and our slippery earth with its moving continents to carry our message to the public. When our science was young, in the decades of the mid-nineteenth century, we satisfied their initial yearning for information with mineral discoveries, with hypotheses on how continents were formed, and, for the collectors, with showy fossils and minerals. As our science grew more mature, we still felt that superficial explanations were sufficient to satisfy the public's desire for knowledge about our earth and to justify our less easily explained research.

Now we ourselves are saying that this is insufficient, that we must carry our science's message to the public in a way that more clearly explains our place in their lives and in a way that explains the limits of our ability to answer their questions. If this is true, who better to speak out for geology than geologists?

And why not speak out for geology? Why not describe the excitement we feel when engaged in our research? Who better understands the ambiguities of the conclusions we reach? The informed citizen will accept some vagueness in our answer when we explain that our geological methods of measurement include the humanly imperceptible, but measurable, dynamic earth processes readable in the rocks and their constituents.

We have no alternative. We must speak out if our sciences are to bring to the public what they demand because it is from the public that we receive our ultimate support. We must **speak out! for geology** because our public deserves our best explanation.

Donald M. Hoskins

State Geologist

EARTH SCIENCE TEACHERS' CORNER

Pennsylvania Rocks Available for Teachers

A set of 24 hand specimens of Pennsylvania rocks is now available from Alfred C. Palmer, who teaches earth science in the Rose Tree-Media School District in Media, Pennsylvania, and nonmajor science at Widener University in Chester, Pennsylvania, and Wilmington, Delaware. The sets of rock samples are keyed to the Pennsylvania Survey's 1:500,000-scale map of the state titled *Rock Types of Pennsylvania* (Map 63). Mr. Palmer visited nearly 20 large outcrops or quar-

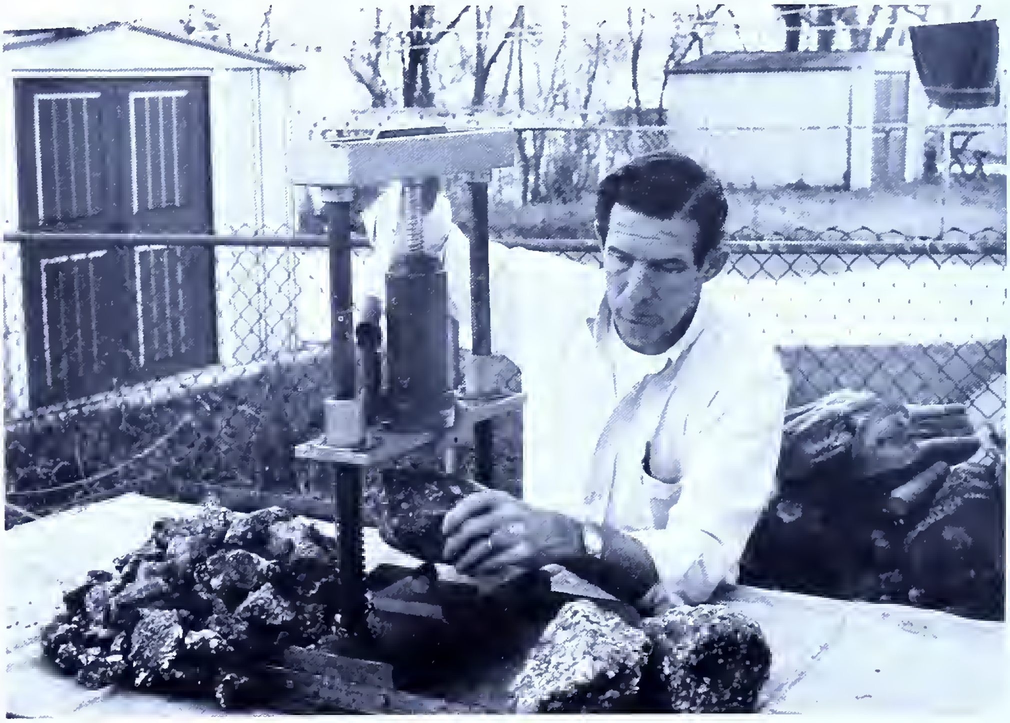

Figure 1. Al Palmer mans his hydraulic rock cracker, "making little ones out of big ones" in his back yard.

ries (cover photograph) during an academic sabbatical at Penncrest High School, collecting tons of rock and traveling thousands of miles within the Commonwealth. He prepared and labeled the hand specimens at home over a period of months (Figure 1), and has assembled a limited edition of 500 display sets. Each set is accompanied by a booklet in which the rock types are described, illustrated, and identified by age, geologic occurrence, and economic or historic legacy. References are listed for further research and background.

A rock set (including Map 63 and the descriptive booklet) may be obtained for a donation of $30.00 from Mr. Alfred C. Palmer, Penncrest High School, 134 Barren Road, Media, Pennsylvania 19063. Checks should be made payable to *The Delaware County Institute of Science*. Revenues accumulated after printing, shipping, and map purchase expenses will be deposited in an account at the Delaware County Institute of Science to be administered as a scholarship fund for earth science education in Pennsylvania. Because of the limited supply of rock sets, Mr. Palmer asks that multiple orders not be requested.

PENNSYLVANIA'S NONFUEL-MINERAL PRODUCTION REACHED $804 MILLION IN 1985

The Mineral Industry of Pennsylvania in 1985 was recently compiled and published by the U.S. Bureau of Mines (USBM) as part of their annual Minerals Yearbook in cooperation with the Pennsylvania Geological Survey. Copies are available free, while supplies last, from the Pennsylvania Geological Survey as Information Circular 96.

This 11-page report, authored by L. J. Prosser, Jr., State Activities Geologist of the USBM, and Robert C. Smith, II, Chief of the Mineral Resources Division of the Pennsylvania Geological Survey, contains notable mining information about the state, including mineral statistics, trends and developments, and reviews of nonfuel-mineral commodities by the USBM. According to Prosser, 1985 was a high-water mark for the value of Pennsylvania's nonfuel-mineral production, which reached $804 million, ranking the Commonwealth eighth in value nationally. Cement, lime, construction sand and gravel, and crushed stone accounted for 97 percent of this total value.

Impressive as this record-high mineral value appears, it mostly reflects continuing higher prices for mineral commodities produced, rather than significant gains in mineral output. The general mineral production trend, measured in short tons, has steadily declined through most of the last decade, whereas the trend of total commodity value has generally risen (Figure 1). The collective average per-ton value of all nonfuel-mineral commodities produced in Pennsylvania has almost doubled since 1975 (total value divided by total tons produced in 1975 equaled $4.61 versus $8.84 in 1985), and is now nearly 20 percent higher than the U.S. average for crushed stone and a whopping 43 percent above the national average for construction sand and gravel, the highest among all 50 states! Likewise, the Commonwealth's cement and lime prices surpass the national average. The average per-ton values and production figures for major mineral commodities produced within the state are listed in Table 1.

These figures reflect many complex manufacturing, marketing, labor, and mining trends, some of which include the higher production costs associated with older, more energy intensive pyroprocess-

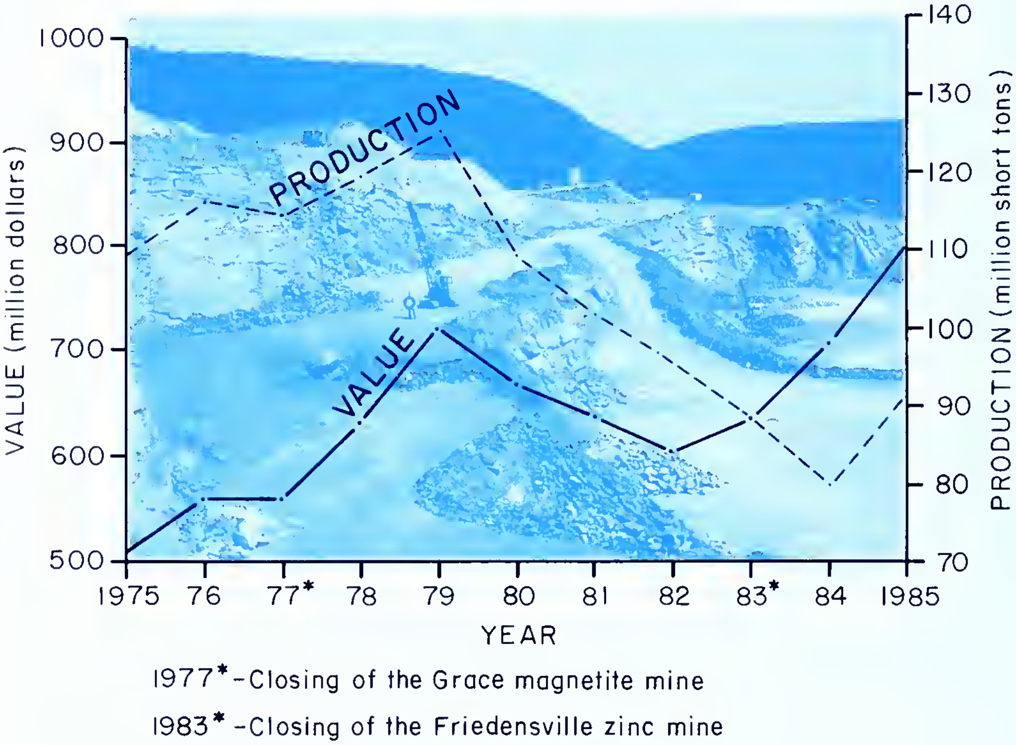

Figure 1. Eleven-year plot of Pennsylvania's nonfuel-mineral production and value. Compiled from the annual Minerals Yearbooks of the U.S. Bureau of Mines (1975 to 1985).

Table 1. *Nonfuel-Mineral Production in Pennsylvania, 1985*

Mineral	*Quantity (thousand short tons)*	*Value (thousands)*	*Price per short ton*
Cement			
Masonry	303	$ 20,970	$ 69.21
Portland	5,535	288,036	52.04
Clays (excludes kaolin)	1,142	5,293	4.63
Lime	1,492	85,269	57.15
Peat	21	602	28.67
Sand and gravel			
Construction	17,000 (est.)	74,000 (est.)	4.35
Industrial	693	9,846	14.21
Stone			
Crushed	64,765	310,859	4.80
Dimension	51	8,214	161.06
Combined value of clays (kaolin), mica (scrap), and other	XX	1,385	
Total	91,002	804,474	

XX = Not applicable.

ing techniques, limited supplies in high-demand areas, high ratios of overburden stripping to ore, and the cost of complying with the state's environmental regulations. Because more than 50 percent of the state's population is located within a 30-mile radius of the international ports of Philadelphia, Erie, and Pittsburgh, it will be a challenge for the Commonwealth's mineral producers to innovate and remain competitive as industrial minerals become true world travelers. For example, the United States imports increasing quantities of aggregate, cement, dimension stone, and lime from as close as Canada and Mexico and as far away as Scotland and Spain. Fortunately, Pennsylvania is well positioned geographically, and historically the mining industry has remained flexible to take advantage of many of the mineral-consuming industries located in the northeastern United States.

REFERENCES

Prosser, L. J., Jr., and Smith, R. C., II (1987), *The mineral industry of Pennsylvania in 1985,* Pennsylvania Geological Survey, 4th ser., Information Circular 96, 11 p.

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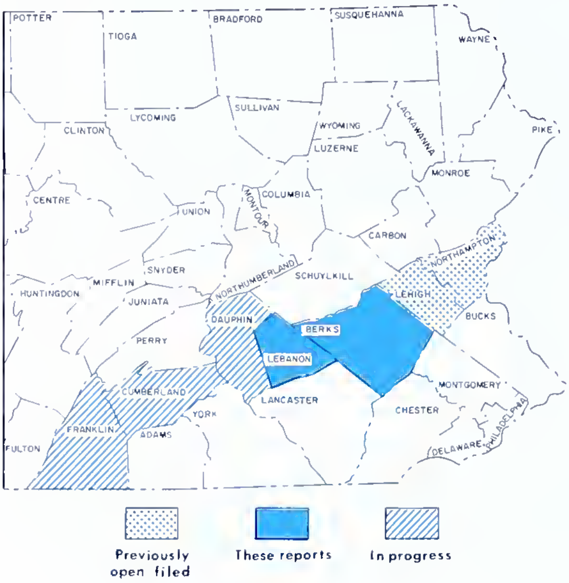
NEW OPEN-FILE REPORTS

SINKHOLES IN BERKS AND LEBANON COUNTIES

The Pennsylvania Geological Survey has announced the release of Open-File Report 88-01, **Sinkholes and Related Karst Features of Berks County, Pennsylvania,** and Open-File Report 88-02, **Sinkholes and Related Karst Features of Lebanon County, Pennsylvania.** The reports, compiled by staff geologist William E. Kochanov, are part of a new series of open-file reports dealing with sinkhole occurrence and distribution throughout all of the limestone regions of Pennsylvania.

The reports consist of 7½-minute topographic quadrangle maps (scale 1:24,000) and a brief explanatory text. The maps depict locations of known sinkholes, contacts of carbonate bedrock formations, structural data for the bedrock, past and present surface-mine locations, caves, and other karst-related features having surface expression. The text contains a brief discussion of the methods used in compiling the report, definitions of some basic terms pertaining to karst geology, and a list of references on the carbonate geology of the county.

The open-file reports for Berks and Lebanon Counties can be examined at the offices of the Pennsylvania Geological Survey, 9th Floor, Executive House, 101 South Second Street, Harrisburg, or copies of the reports can be purchased by mail order at the prepaid copying and shipping cost of $30.00 for the Berks County report and $15.00 for the Lebanon County report. Direct mail orders to the Pennsylvania Geological Survey, Department of Environmental Resources, P. O. Box 2357, Harrisburg, PA 17120. Checks should be made payable to *Commonwealth of Pennsylvania*.



The Paleoecology of the Swatara Gap Fauna

by David Lehmann

Swatara Gap (in Lebanon County) is a popular and well-documented site for collecting Ordovician fossils (Figure 1). Here, the siltstones and mudstones of the Martinsburg Formation contain an abundant, diverse fossil fauna. Beautifully preserved, limonite-stained casts and molds of trilobites, brachiopods, mollusks, echinoderms, and other organisms attract fossil collectors from all over the United States.

Although the Reedsville Shale (a western correlative of the Martinsburg Formation) is fossiliferous, other Martinsburg rocks in the eastern part of the state typically contain very few fossils. This indicates that the sediments that formed the Martinsburg rocks at Swatara Gap were deposited in a different environment than the

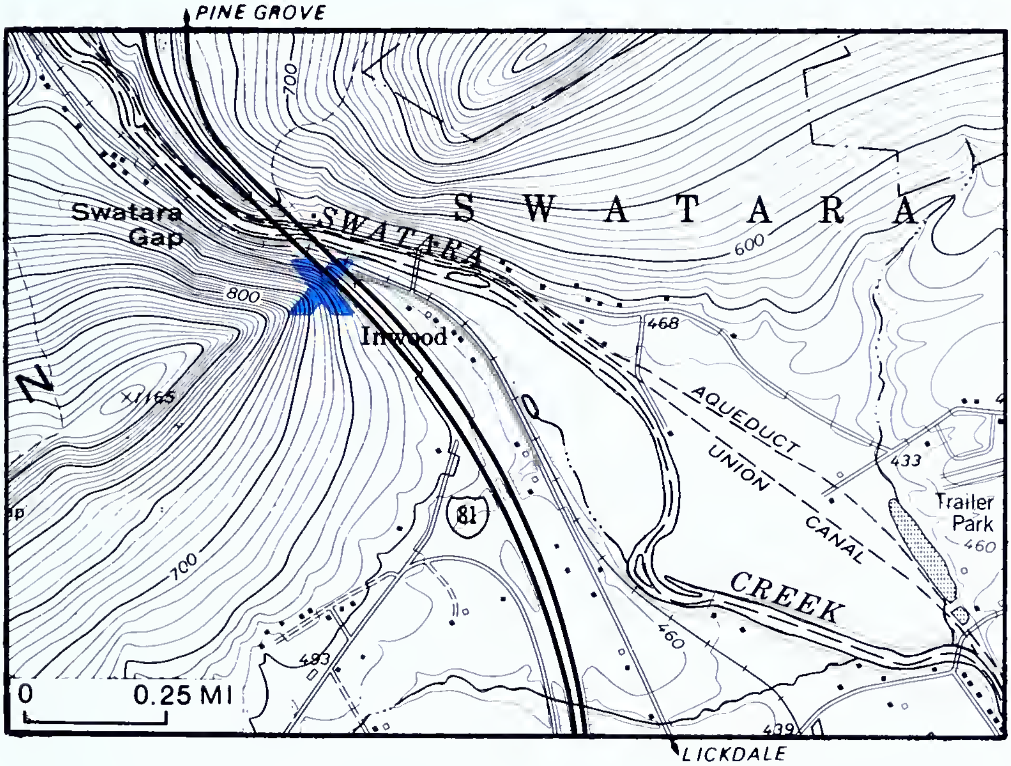


Figure 1. Location of the fossil-collecting site (x) at Swatara Gap.

sediments that formed other nearby Martinsburg rocks. Until now most geologists considered the Swatara Gap rocks to be the result of deep-sea deposition. Although most of the Martinsburg rocks seen at other eastern Pennsylvania localities are probably the result of deep-water deposition, a deep-sea environment cannot adequately account for the fossils and sediments seen in Swatara Gap rocks.

Why a Deep-Sea Explanation Does Not Work for Swatara Gap Rocks

Benthic (bottom-dwelling) fossils occurring in deep-water sediments may represent either transported or *in situ* assemblages. If the Swatara Gap fossils represent a transported assemblage, we would expect the shells to have become disarticulated, broken, and abraded as they bounced and rolled on the sea floor. These are typical characteristics of transported shells. Most of the fossils from Swatara Gap do not show any characteristics of transport, clearly indicating that these shells were not transported a great distance. On the contrary, many of the Swatara Gap organisms appear to have been buried in their life positions.

Because the Swatara Gap fossils represent an *in situ* fauna, sediments and sedimentary structures can be used to help us recognize the paleoenvironment. The Martinsburg rocks from Swatara Gap are extremely fine grained, much finer grained than nearby typical deep-sea Martinsburg deposits. In deep-water deposits, the grain size of sediments becomes increasingly coarser towards shore (Irwin, 1965). This means that if the Swatara Gap rocks result from deep-water deposition, they represent an even deeper environment than other nearby Martinsburg rocks. However, these other Martinsburg rocks lack benthic fossils, presumably because the water near the sea floor was too deep to contain enough oxygen to support life. Therefore, it seems unlikely that finer grained sediments of still deeper water could support an abundant benthic faunal assemblage.

Clues to Interpreting the Depositional Environment

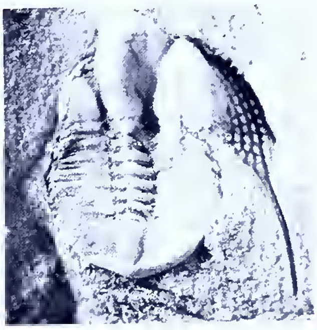
The extremely fine grains in the Martinsburg rocks at Swatara Gap indicate that these sediments were deposited in a low-energy environment. The rocks contain abundant trace fossils, indicating a well-oxygenated sea floor. A few of the rocks contain herringbone cross-laminations. In herringbone cross-laminations, very thin laminae (or layers) of sediments are inclined in opposite directions. Herringbone cross-laminations form as the result of the bidirectional flow of incoming and outgoing tides.

This combination of sedimentary features, indicating a low-energy, well-oxygenated bottom and tidal-current influence, implies that the Swatara Gap sediments were deposited in a very shallow environment. Along very gently sloping coastlines, low-energy zones can exist shoreward of where waves break. Because waves have expended all of their kinetic energy, they do not strongly influence deposition in the shallow, low-energy zone.

The Ecology of the Fossil Organisms

Certain characteristics of trace fossils in the Swatara Gap rocks suggest that the sediments contained a large amount of water. Fine-grained sediments having high water content create a very soft sea floor. The Swatara Gap fauna was well suited for this soft substrate. The most abundant fossil organism, the blind trilobite *Cryptolithus bellulus* (Figure 2), burrowed in sediments.

Figure 2. Fossil trilobite *Cryptolithus bellulus* Ulrich from Swatara Gap, x4.



Brachiopods, an abundant group of fossils in the Swatara Gap rocks, are represented by flat-shelled and very small varieties (Figure 3). Flat-shelled and small brachiopods have a low ratio of mass to surface area, which means that the weight of the brachiopods was distributed over a relatively large area. This prevented the brachiopods from sinking into the soft substrate in the same manner that snowshoes prevent a person from sinking in uncompacted snow. Some of the brachiopods (*Leptaena* and *Rafinesquina*) have wrinkled shells. These wrinkles, or rugae, may have helped to anchor the shell and keep it from sliding on the muddy substrate.

How Shallow is "Shallow"?

The Martinsburg sediments at Swatara Gap were apparently deposited slightly below and slightly above average low tide (subtidal and intertidal zones).

The subtidal deposits contain lenses and layers of fossiliferous siltstones and mudstones. Many of the subtidal organisms con-

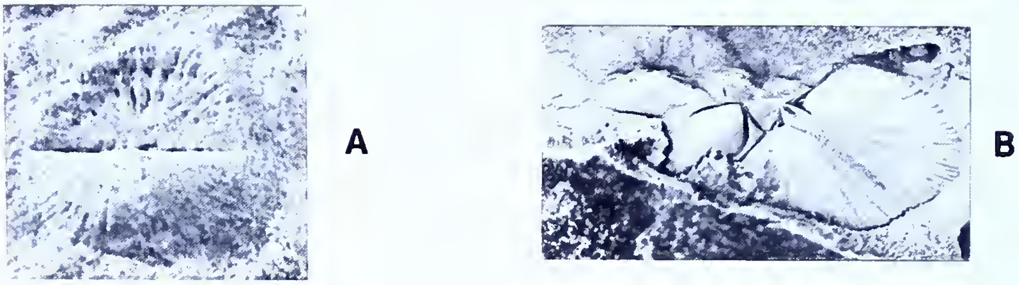


Figure 3. Fossil brachiopods from Swatara Gap. A. *Sowerbyella plicatellus* (Ulrich), interiors of both valves, x8. The brachial valve is at the top of the photograph. B. *Onniella multisecta* (Meek), interiors of both a pedicle valve (left) and a brachial valve (right), x2.

sumed organic matter suspended in the water and buried in the sediments. Brachiopods consumed suspended nutrients close to the sea floor, whereas crinoids consumed suspended nutrients slightly higher off the floor. Some trilobites (*Isotelus* and *Gravicalymene*) scavenged the sea floor for food, whereas *Cryptolithus* and pelecypods consumed food in shallow deposits. Worms burrowed within the sediments, consuming organic matter, but also pushing nutrients up closer to the sediment-water interface. Nautiloids and eurypterids preyed upon these other organisms.

The lower intertidal environment is represented by mudstones and shales. Because this environment was located further from a high-energy source (waves), its sediments are slightly finer than the sediments of the subtidal environment. Organisms in an intertidal environment need mechanisms to avoid drying out during low tides. Not surprisingly, most of the fossil organisms in the intertidal deposits at Swatara Gap are burrowers, for instance, infaunal pelecypods and the inarticulate brachiopod *Pseudolingula*. Because these organisms could withdraw into burrows, they remained moist when topmost sediments dried.

The "Big Picture"

It may seem very unusual that this shallow-water Martinsburg deposit is geographically close to deep-water Martinsburg deposits. However, the rocks at Swatara Gap are younger than other nearby Martinsburg rocks. The older Martinsburg sediments were deposited in a young, deep sedimentary basin. Although the basin was subsiding, sediments filled it more quickly than it subsided. By the time the Martinsburg sediments at Swatara Gap were deposited, the basin was filled nearly to sea level.

Furthermore, the rocks at Swatara Gap may not be in their original position. This region of the state is structurally complex, and the Swatara Gap rocks may be part of a large block that has been transported. However, geologists need a more complete understanding of the deep structures of eastern Pennsylvania before the complete structural history of the Swatara Gap rocks can be interpreted.

A Final Thought or Two

The ecology of an organism may be defined as its interactions with its environment and other organisms. Before we can understand the ecology of a particular organism, we must first be able to identify and interpret its environment. The sedimentary structures of the rocks at Swatara Gap indicate that the sediments were deposited in very shallow water.

Organisms are typically well suited for their environments; they have mechanisms for avoiding the dangers and maximizing the opportunities presented by their environments. The fossil fauna of the Swatara Gap rocks illustrates this principle. The muddy substrate and low energy were important physical parameters of the paleoenvironment, and the fossil organisms were well adapted for these parameters.

REFERENCE

Irwin, M. L. (1965), *General theory of epeiric clear water sedimentation,* AAPG Bulletin, v. 49, p. 445-459.

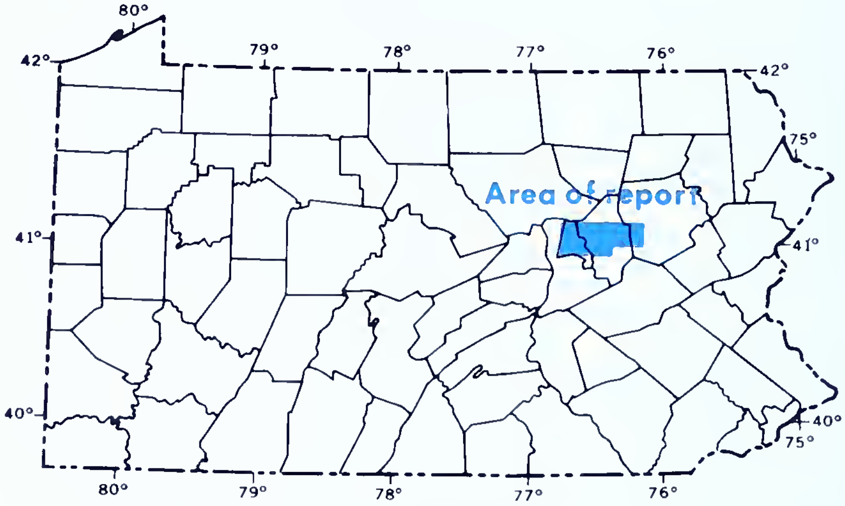
NEW PUBLICATION

Groundwater Resources of the Berwick-Bloomsburg-Danville Area

Recognizing groundwater as an important, and in many communities a primary, source of water supply, the Pennsylvania Geological Survey has undertaken numerous studies of Pennsylvania's groundwater resources. Water Resource Report 61, **Groundwater Resources of the Berwick-Bloomsburg-Danville Area, East-Central Pennsylvania,** is the most recent publication to be released as part of this continuing appraisal. Prepared in cooperation with the U.S. Geological Survey, this study concerns the hydrogeologic system of the North Branch Susquehanna River and surrounding uplands. The study area covers parts of Columbia, Luzerne, Montour, and Northumberland Counties. The report was written by John H. Williams and David A. Eckhardt.

The groundwater flow system of the study area is discussed as well as the hydrogeologic characteristics of individual formations within the area. Topics covered include the water budget, estimates of recharge, groundwater movement, discharge, potential yields, well depth, and water quality. A full-color geologic map and cross sections of the glacial-outwash aquifer are also included.

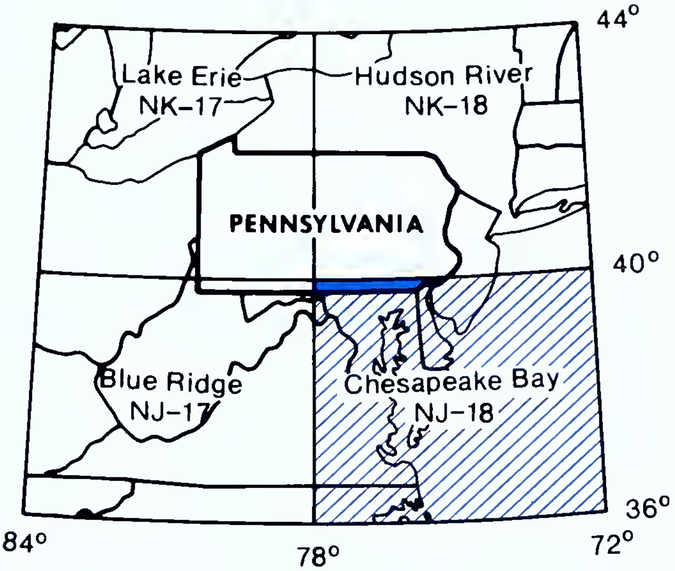
A number of aquifers capable of yielding large amounts of good-quality water are present in the study area. It has been determined that about 25 percent of the wells completed in the outwash sand and gravel are capable of yielding 410 gallons per minute or more, and the same percentage of wells completed in the Keyser and Tonoloway Formations are capable of yielding 620 gallons per minute or more.



Groundwater is the main source of supply within much of the area covered in this study. Thus, the report will be of interest to all those concerned with obtaining, maintaining, and protecting this valuable resource.

Copies of the report can be ordered from the State Book Store, P. O. Box 1365, Harrisburg, PA 17105; the price is $10.10 (plus 60¢ tax for Pennsylvania residents). Checks should be made payable to *Commonwealth of Pennsylvania*.

Pennsylvania Surficial Materials Included in Quaternary Geologic Atlas of the United States



Quaternary Geologic Map of the Chesapeake Bay 4° x 6° Quadrangle, United States (Cleaves, E. T., and others, 1987, U.S. Geological Survey Miscellaneous Investigations Series I–1420 [NJ–18]) is part of the Quaternary Geologic Atlas of the United States being compiled and published at 1:1,000,000 scale by the U.S. Geological Survey, and is the first of the published maps to include part of Pennsylvania. The map encompasses the portion of Pennsylvania south of latitude 40° and east of longitude 78°. This well-printed full-color map shows topographic contours at 50-, 100-, and 150-m intervals, major roads, limited drainage, and the areal distribution of 65 lithologic units ranging in age from Holocene to Pliocene. Fifteen of the units occur on the Pennsylvania portion of the map. The brief and generalized map-unit descriptions cover texture and mineralogy, morphology (where significant), notable variations and inclusions, and thickness. Map units include mainly varieties of alluvium, colluvium, marine and estuarine sands and silts, residuum, and saprolite. A limited bibliography provides an adequate introduction to the literature. This map, the cooperative effort of nine state compilers including William D. Sevon of the Pennsylvania Geological Survey, and three editors/integrators from seven organizations, is one of 53 anticipated maps covering the conterminous United States and one of four that will include parts of Pennsylvania. This new series of maps is valuable because it provides information not previously available; however, users must be aware that the information is not adequate to answer site-specific questions.

STAFF GEOLOGISTS RECEIVE AWARDS

Clifford H. Dodge

Survey Geologist Clifford H. Dodge was a recent recipient of the Secretary's Award for Performance Excellence. He received the award at the Department's Employe Recognition Program Awards Luncheon, which was held on October 27, 1987. Dodge, a member of the Geologic Mapping Division, was recognized for his sustained superior overall performance in mapping the bituminous coal geology of western Pennsylvania and in contributing to numerous other Survey projects and activities, many of which have helped to promote the importance of geology to the citizens of our Commonwealth.

With award in hand, Dodge is flanked by Deputy Secretary for Resources Management James R. Grace (left) and Secretary of Environmental Resources Arthur A. Davis.

Christopher D. Laughrey

Christopher D. Laughrey, a geologist in the Oil and Gas Geology Division of the Survey, received a Certificate of Merit award at the annual meeting of the Eastern Section of the American Association of Petroleum Geologists in Columbus, Ohio, in early October 1987.

The award reads that Laughrey "has served with distinction the Eastern Section of the American Association of Petroleum Geologists as General Chairman, Pittsburgh Meeting during the period of 1984 and is presented this certificate of merit in recognition of outstanding service to the membership."

Paul A. Catacosinos, President of the Eastern Section of AAPG, presents award to Laughrey. Photograph courtesy of Jorge Valdez, Samuel T. Pees and Associates, Meadville, Pennsylvania.

NEW STAFF MEMBER

Garry L. Price

Garry Price joined the Environmental Geology Division of the Survey in November 1987. He is responsible for geophysical investigations. Garry acquires and processes seismic and earth-resistivity measurements which, combined with current geologic knowledge, are used to interpret shallow subsurface structure and stratigraphy. The geophysical information obtained will assist the geologists in locating buried aquifers, sinkholes, and other underground geologic features.

Garry was an X-ray technician in the army from 1973 to 1976. After the army, he attended Eastern Kentucky University in Richmond, Kentucky, where he received a B.S. in geology in December 1978 and an M.S. in geology in December 1980. Garry then worked as a geologist in the exploration division of Amoco Production Company from 1980 to 1986. His territory was primarily the Permian basin in Texas and New Mexico.

Geochips

In the summer of 1934 Stan Lohman, a cooperating groundwater geologist of the U.S. Geological Survey, and the late Bradford Willard, paleontologist and Devonian specialist of the Pennsylvania Geological Survey, were both doing field work in south-central Pennsylvania. For a week or so Stan, his wife Ruth, and Brad stayed at the same hotel in Huntingdon, and often had a late dinner together, during which Brad generally told interesting stories concerning mutual friends, for he was an adroit storyteller. One concerned the late John B. Reeside, Jr., later to become the distinguished Chief of the U.S. Geological Survey Section (later Branch) of Paleontology and Stratigraphy. During the mid-teens John was working a detailed study of the Helderberg Limestone of central Pennsylvania as a thesis for a doctor's degree, which was awarded to him in 1915 by Johns Hopkins University (later published as U.S. Geological Survey Professional Paper 108-K). John traveled by horse and buggy and stretched his meager funds by obtaining board and room at a succession of farmhouses. One late afternoon he knocked at the door of a farmhouse, and was confronted by a huge stern-faced Pennsylvania Dutchman. John explained the nature of his needs, while the farmer looked him up and down but remained silent. Finally the man barked with no change in expression: "Vell—ve'll sleep you, but-you-gotta-eat-yourself!"

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IN COOPERATION WITH THE U.S. GEOLOGICAL SURVEY

TOPOGRAPHIC MAPPING
GROUNDWATER-RESOURCE MAPPING

GROUNDWATER LEVELS
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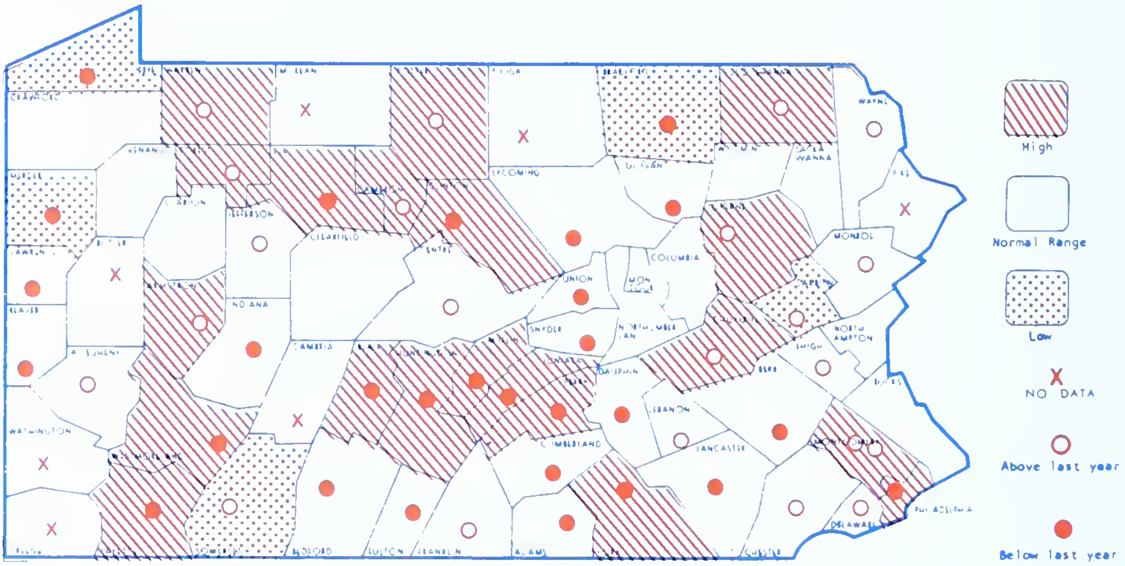

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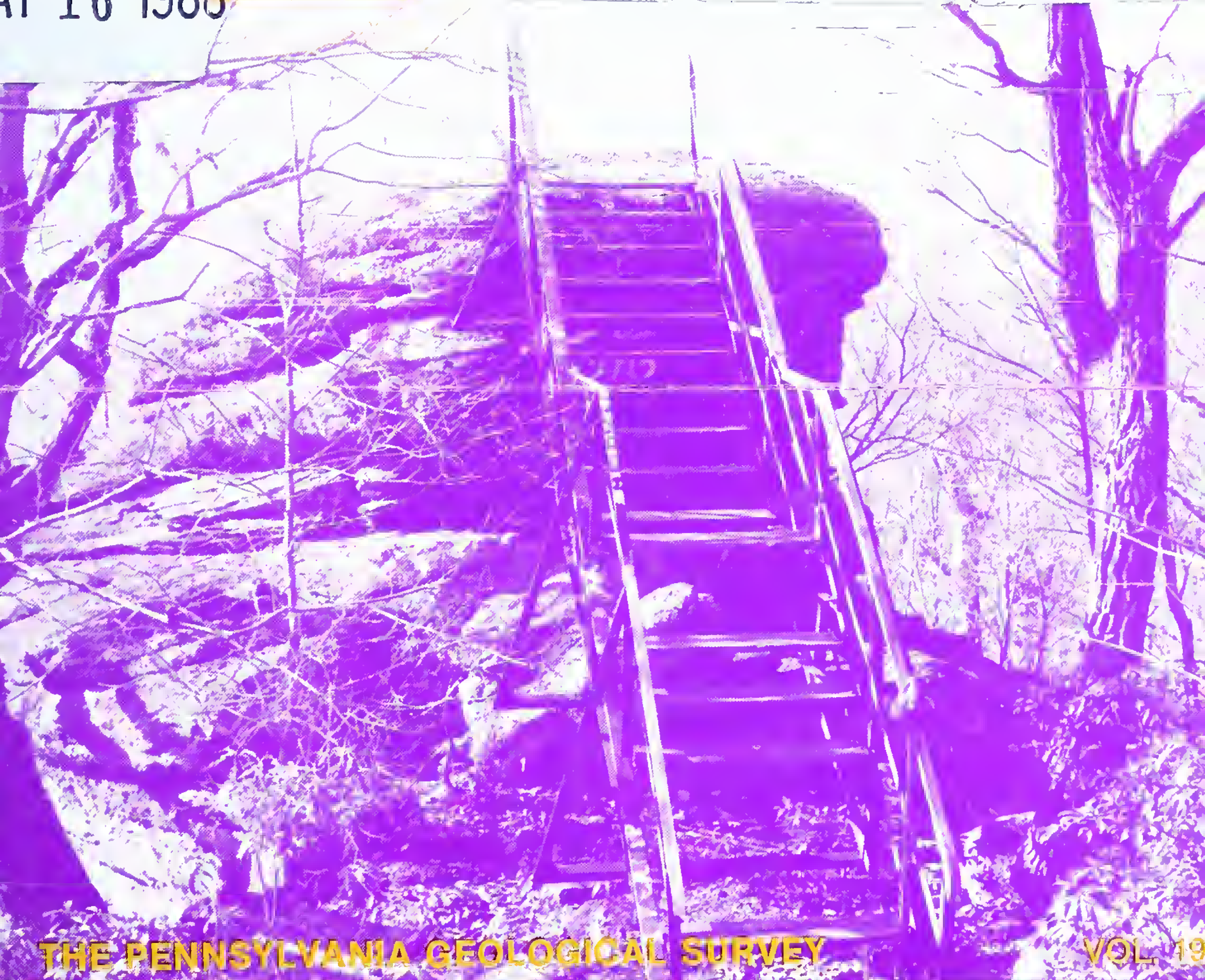

THE PENNSYLVANIA GEOLOGICAL SURVEY

VOL. 19

COMMONWEALTH OF PENNSYLVANIA
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ON THE COVER: Prospect Rock, a tor of Pottsville conglomerate, on Green Mountain about 3 miles west of Freeland, Luzerne County. As the name suggests, the top of this rock "tower" affords a spectacular view of the Conyngham Valley to the west. Photograph by J. D. Inners.

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Editor, Christine M. Dodge

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The Packaging of Geology

Geologists have a problem. We have a serious problem in the packaging and marketing of our products. The specific problem addressed here is one of the forms we frequently use to package the results of our geological investigations.

I have just returned from the annual meeting of the Northeastern Section of the Geological Society of America. At this meeting over 325 scientists made oral and poster presentations of investigations they have conducted. Each of these presentations represents many weeks, months, and even years of painstaking work at considerable public or private expense. Many of these presentations were carefully prepared, and then presented in a clear and succinct style.

The problem is that many of the presentations were not carefully prepared nor were they delivered in an acceptable manner. Some speakers did not prepare illustrations designed to convey complex geologic information quickly and easily in the brief allotted time. Most often these speakers delivered their message in such a poor manner that their audience lost interest or could not fathom the meaning. Some speakers exceeded their time limit and were asked to stop before they had even reached their conclusions, if, indeed, they had any conclusions to reach.

Geology can no longer afford such lack of excellence at meetings of colleagues. These regional meetings are often the first exposure of students to one of the principal styles for presentation of geological research. To see their fellow students and, worse, their teachers and other geologists deliver abominable presentations is to teach them that excellence in communicating geology is not important and that the manner of presentation of the results of their hard work is subordinate to their research or of no concern whatsoever.

If geology is to be influential in contributing to the commonweal, and pivotal in resolution of environmental concerns of our fellow citizens, we must teach ourselves and our students that the packaging of our work through written and oral presentations is critically important. Firstly, we must demand that we speak clearly to ourselves, the audience most likely to understand our message. Then we must demand that we go further and speak understandably to audiences untrained in geology, a task considerably more difficult than communicating with colleagues.

If a geologic investigation is worth all of the resources devoted to its completion, it is worth the effort to explain it to all. To do less is to say that our science is of little or no value.

Donald M. Hoskins

Donald M. Hoskins
State Geologist and Curmudgeon

Tors and Surficial Weathering Phenomena in the Pottsville Conglomerate of the Hazleton Area

by Jon D. Inners
Pennsylvania Geological Survey

> "Our wagonette had topped a rise and in front of us rose the huge expanse of the moor, mottled with gnarled and craggy cairns and tors."
>
> Sir Arthur Conan Doyle (1930),
> *The Hound of the Baskervilles*

In his chilling story of murder on the Cornish moors, Sir Arthur Conan Doyle provides the attentive reader with a vivid description of some striking geologic features that are common not only in the extreme southwest of England but also in many other parts of the world. He notes that the rocky prominences, or "tors," of Cornwall are "gnarled and craggy," that their "fantastic shapes" jut out "upon the. . .skyline," and that "sheer cliff[s]" overlook "stone strewn slope[s]."

A tor (from the Celtic *tor,* meaning tower) is an isolated, residual mass of jointed and fissured bedrock that projects from the slope or top of a hill. Although considerable controversy exists as to the origin of these often spectacular features, workers who have studied the classic tors of Devon and Cornwall in England generally believe that periglacial frost riving has had an important influence on their present conformation (see Twidale, 1971, and Embleton and King, 1975). Tors can form in any massive or very thickly bedded rock in which joints (i.e., planar fractures) are widely spaced. Whereas those haunted by the "Hound" on the Dartmoor in Cornwall are composed of granite, most periglacial tors in Pennsylvania occur in thick-bedded sedimentary rocks (particularly sandstones and conglomerates) of the Valley and Ridge and Allegheny Plateaus provinces.

In the Hazleton area of northeastern Pennsylvania, tors are splendidly developed in the upper part of the Pennsylvanian-age Pottsville Formation (probably the Sharp Mountain Member of Wood and others, 1956). This rock unit forms an escarpment surrounding the high "plateau" of the main Eastern Middle Anthracite field. Many tors occur on this mountainous rim, and others are situated on the crests or slopes of the several anticlinal ridges that trend roughly east-west across the area. The tors that are the subject of this paper are located as follows (Figure 1):

(1) At the western nose of Green Mountain, 4.5 km (2.8 mi) west of Freeland ("Prospect Rock") (41°01′17″N/75°57′10″W, Freeland quadrangle; cover photo);

(2) Above a cut on an abandoned railroad grade, 1.1 km (0.7 mi) east of Ashmore Yards (40°57′46″N/75°53′03″W, Hazleton quadrangle; Figure 2);

(3) Within the southernmost city limits of Hazleton near the Hazleton Water Authority water tank on Pisemire Ridge, 0.7 km (0.4 mi) north-northeast of Jeansville (40°56′00″N/-75°58′06″W, Hazleton quadrangle; Figure 3);

(4) At the head of Sugarloaf Creek valley on a southern spur of Little Sugarloaf Mountain near the Humboldt Fire Tower, 4 km (2.5 mi) west of Humboldt (40°56′03″N/76°05′30″W, Conyngham quadrangle).

Pottsville conglomerate of the Hazleton area is typically a very thick bedded, light-gray to white orthoquartzitic rock that contains abundant rounded vein-quartz and metaquartzite pebbles 1 to 4 cm (0.4 to 1.6 in.) in diameter. At most outcrops, conspicuous planar joints are spaced 0.3 to 5 m (1 to 16 ft) or more apart. The fact that

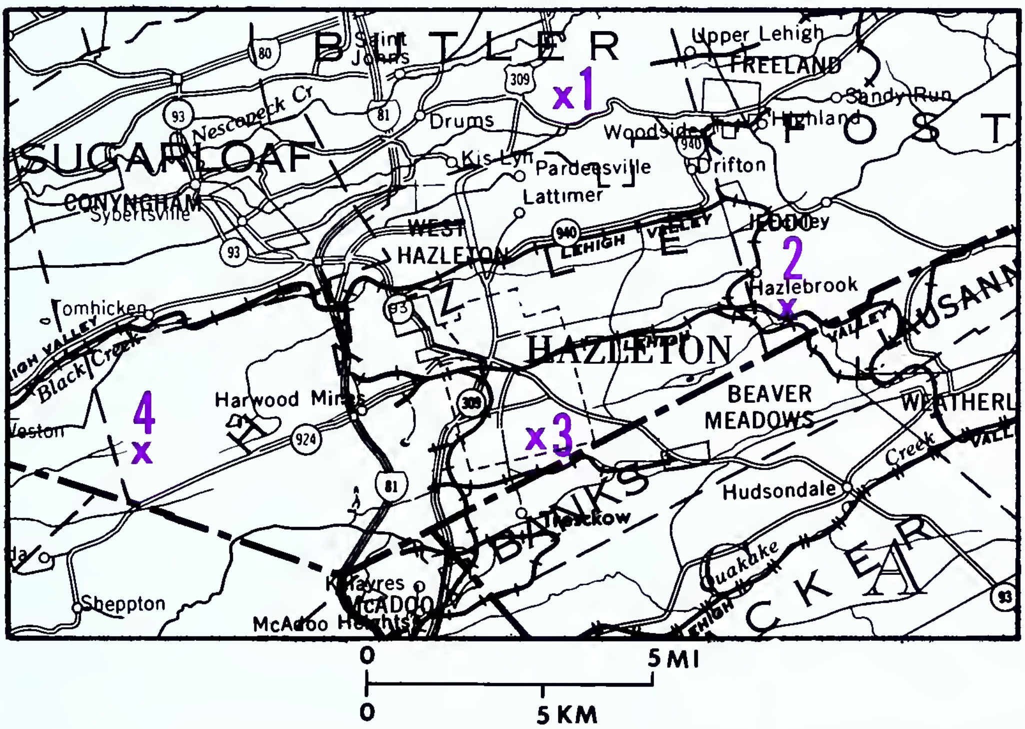


Figure 1. Map showing some Pottsville tor localities in the Hazleton area.

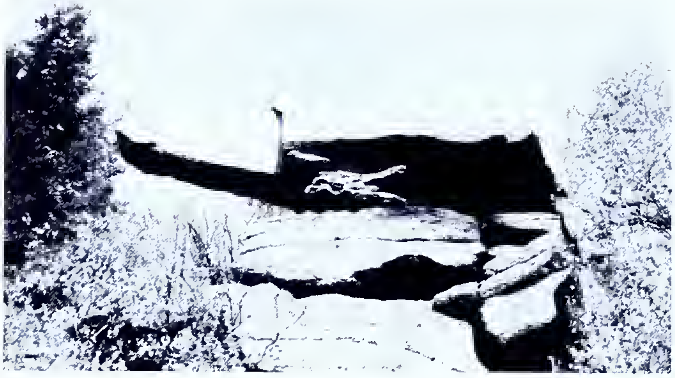


Figure 2. "Turtle Rock" at locality 2. This tor is both a pedestal rock and a rock statue. It is approximately 4 m (13 ft) long.

many of these joint fractures are "open" gives even relatively intact ledges a distinctive shattered appearance. In thin section, the pebbles are seen to be enmeshed in a matrix of medium to coarse, subangular quartz sand grains (Figure 4). Both pebbles and sand grains exhibit pressure-solution suturing at their contacts. This pressure solution (and subsequent redeposition) of silica accounts for most of the siliceous cement holding the rock particles together. Small patches of illite (fine-grained "mica" derived from the diagenetic recrystallization of clay) that occur locally form a much less important binder (see Figure 4). Possibly because of the coarse grain size of the sand and the rounded nature of the pebbles, cementation of the conglomerate varies considerably in intensity. The surfaces of most outcrops and boulders are friable, and the rock readily breaks down to a sandy gravel probably identical in texture to the unconsolidated gravel that accumulated as sand bars in the ancient Pennsylvanian streams nearly 315 million years ago.

The Pottsville tors are best developed where the dip of the strata is very gentle (less than 20 degrees) (see Figures 2 and 3). Subvertical joints in these gently dipping ledges are typically open 6 cm (2.4 in.) or more; in some places they open up to form joint caves

Figure 3. Two of several conglomerate tors at locality 3. Note the open joints and the incipient development of pedestal-like masses of rock.

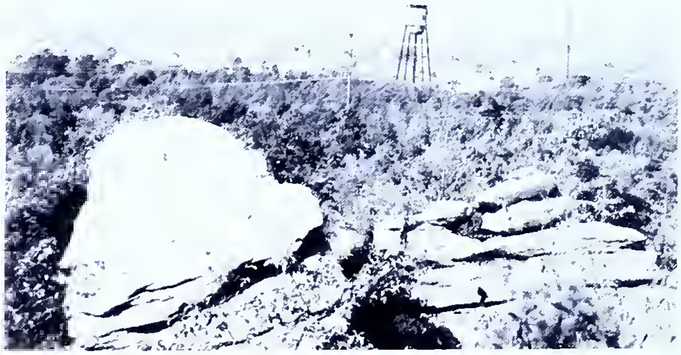
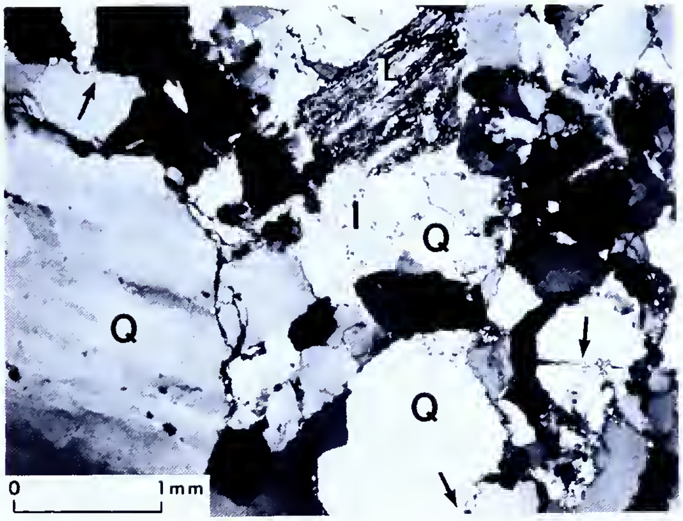


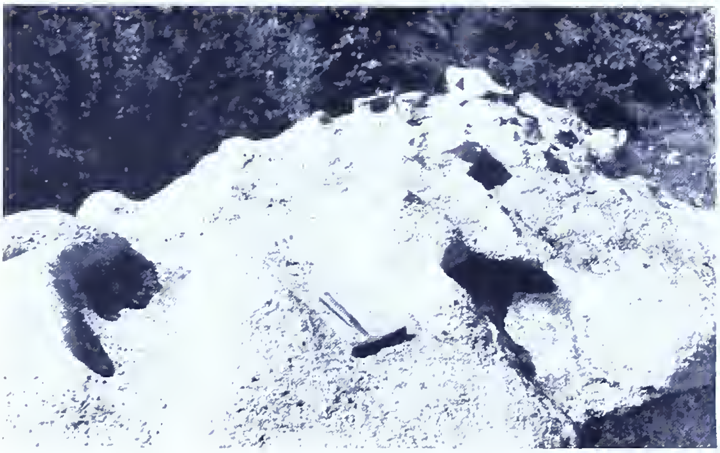
Figure 4. Photomicrograph of thin section of quartz conglomerate of the upper Pottsville Formation at locality 3. Note the framework of quartz grains and pebbles (Q), the few patches of illite (I), the sutured grain contacts (arrows), and the rare lithic grains (L).



several meters across (as at locality 2). Rough, picturesque crags that commonly form on steeper dips generally lack the towerlike configuration and occasional joint cave of classic tors. The deep surficial weathering phenomena described below, however, are often as conspicuous on the more steeply dipping ledges as on the subhorizontal ones.

Much of the interest in the conglomerate tors of the Hazleton area derives from their intricate, surficial sculpturing. In most cases, this takes the form of pan-holes (Palmer and Radley, 1961), cusps, and deep ruts that pockmark the rock surface to depths of up to 30 cm (12 in.) (Figure 5). This alveolar (i.e., pitted) weathering (Twidale, 1976) in some places gives rise to tortured, grotesque "statues" (Figure 6). Twidale (1971) explains the pits as resulting from the gradual deepening and lateral expansion of minute depressions in the rock surface through the freeze-thaw action of water/ice ponded in the depressions. Over a period of many years, as these freeze-thaw cycles (aided perhaps by alternate wetting and drying in warmer times) cause loosening of the grains on the edges and bottoms of the depressions, a conspicuous "pothole" gradually forms. The evacuation of debris from the deepening pits in most cases takes place during exceptionally heavy rains when (1) the splattering of large raindrops causes saltation of loose sand and granules out of the pits, and/or (2) loose material is washed out through ruts that are gradually eroded in the edges of the pits by overflowing water. "Turbulent eddies of air" may blow out some of the fine sand (Twidale, 1971).

A two-stage origin for the Pottsville tors of the Hazleton area seems most likely (see Embleton and King, 1975). Stage one was intense



A. Pan-holes and weathering cusps.

B. Pan-hole and rut (formed by overflow of water from the depression).

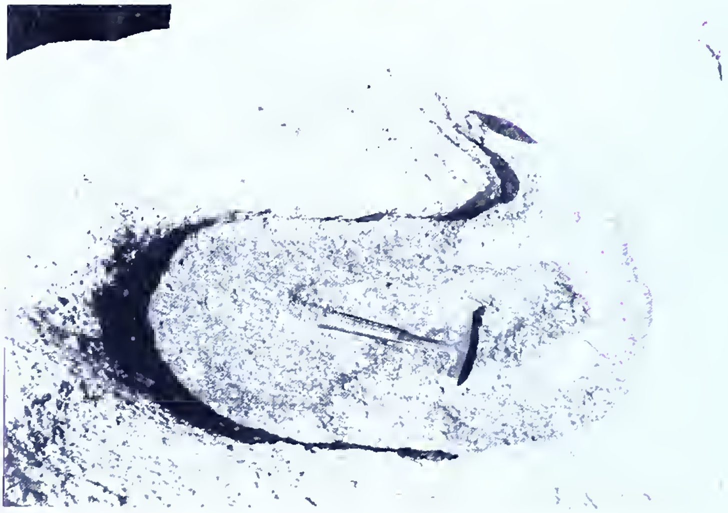


Figure 5. Weathering phenomena on the Pottsville tors at locality 2. The hammer is 28 cm (11 in.) long.

chemical and physical weathering under the warm, humid climatic conditions that existed in early to middle Tertiary time (50 to 25 million years ago) (see Sevon, 1985). During this period a thick soil cover developed over the Pottsville outcrop, but "incipient tors" formed beneath this regolith in areas of widely spaced joints. Erosional exhuming of these more resistant bedrock masses took place slowly during the succeeding eons, perhaps accelerated somewhat by Illinoian(?) glaciation about 300,000 years ago. By the Sangamonian Interglacial Stage (150,000 years ago) the tors had become partially exposed and subject to alveolar weathering. Stage two involved frost riving and dominantly physical mass wasting under the rigorous periglacial climatic regime of the late Wisconsinan (20,000 to 10,000 years

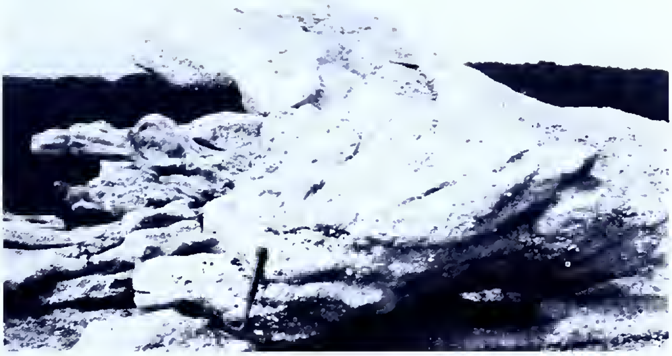


Figure 6. Intensely weathered tor at locality 4. The grotesque rock statues here appear to result from minor differences in cementation within the thick, crossbedded conglomerate beds. The hammer is 28 cm (11 in.) long.

ago). It was at this time that the tors took on their fissured, craggy aspect. Weathering continued to accentuate the surficial irregularities throughout this frigid episode and into the gradually warming postglacial period. The facts that some "potholes" extend down through a brown, oxidized weathering rind several centimeters thick into light-gray, unoxidized rock below and that many pits contain loose material weathered *in situ* suggest that the formation of the pits and rills is an active process wearing away the tors at the present time (see Palmer and Radley, 1961).

The author thanks Duane Braun of Bloomsburg University for his assistance in devising a chronology of tor development. Henry Schasse, now with the Washington Geological Survey, noted the "pothole" weathering of the Pottsville conglomerate when mapping the Conyngham quadrangle in the late 1970's.

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Conodonts Confirm that the Conemaugh Marine Unit at Ebensburg *IS* Ames

by Glen K. Merrill
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Locality and Samples

Brady and others (1985) described a locality in Ebensburg, Pennsylvania, and questioned what marine unit is exposed there. The locality is roughly 1.3 km (0.8 mi) west of the center of town and just north of U.S. Route 422 on the grounds of Bishop Carroll High School in Ebensburg, Cambria County (40°29′12″N/78°44′20″W; Figure 1). Although they concluded that the exposure was probably Ames, Brady and his colleagues were not able to exclude the possibility that it might be one of the older Conemaugh units such as Pine Creek or Brush Creek because it exhibited some megafaunal characteristics common to both the Ames and Brush Creek marine zones of the Glenshaw Formation, Conemaugh Group. A part of their doubt stemmed from the fact that this locality is relatively isolated from the main part of the western Pennsylvania coal field, occurring almost on the Allegheny Front.

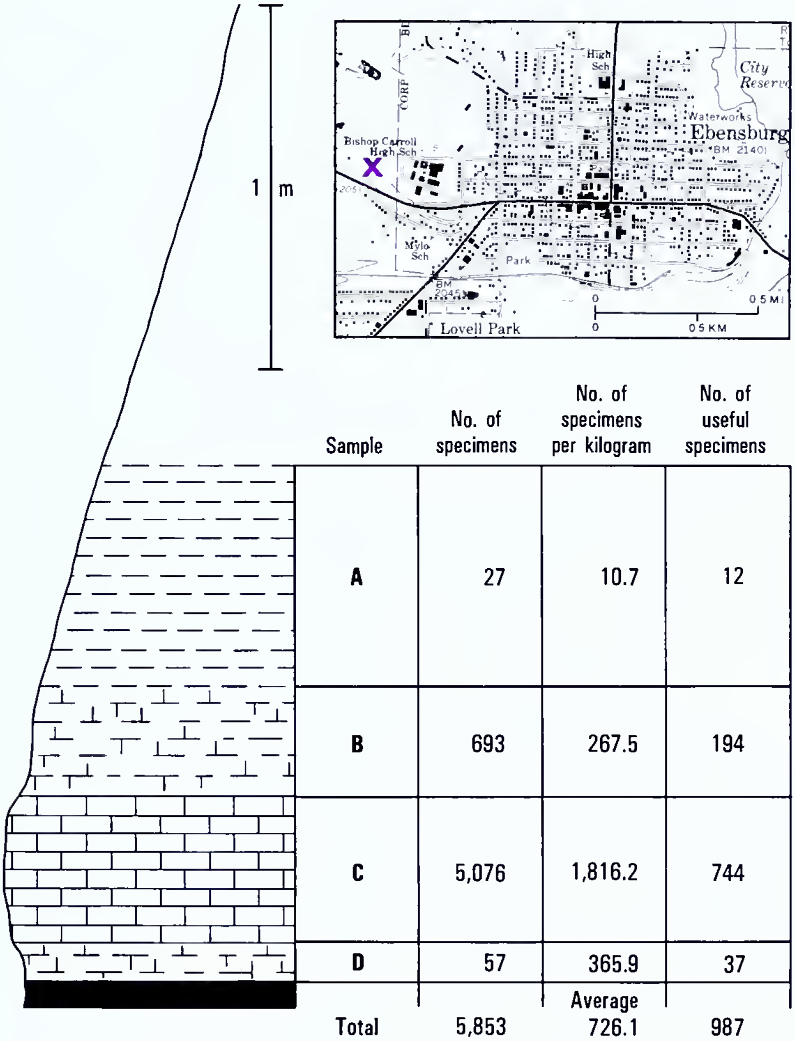
In July 1986 the author had the opportunity to visit, examine, and sample the Ebensburg locality for conodonts in hopes of resolving this ambiguity. Over the past few decades this group of microfossils has proven itself to be the single most reliable one for indicating the ages of Paleozoic sedimentary rocks. In some parts of the stratigraphic column conodont-based biostratigraphic zones whose durations were considerably less than 1.0 million years have been established. Although the zones established for the Pennsylvanian in the central Appalachians (Lane and others, 1971) are not that restricted, Sando (1977) estimated that they had an average duration of about 2.5 million years, a level of resolution making the distinction between Brush Creek and Pine Creek fairly easy, and the distinction of either from the Ames extremely easy.

Processing and Residues

Shales were reduced with varsol. Limestones and the shale residues were treated with acetic acid followed by formic acid. All samples yielded a large volume of residue. Examination of these residues showed that a major proportion of them consisted of whole and fragmented micro-mollusks, both low- and high-spired gastropods and clams. Brachiopods were present in some numbers as well, and pyritized chonetids were especially conspicuous. Ostracodes were also present. Most of the mollusks appear to have been replaced by silica. The samples were further concentrated by several processing techniques described in Austin (1986). The final concentrates were a very small portion of the original residues and picking was easy, although time-consuming.

The Conodont Fauna

Conodonts are common to abundant in all four samples, the highest abundances (frequencies) occurring in samples B and C (Figure 1). Preservation ranges from good to very poor due, at least in part, to the rigorous techniques necessary to disaggregate the rocks that contained them. Many of the specimens show some evidence of partial dissolution.



Sample	No. of specimens	No. of specimens per kilogram	No. of useful specimens
A	27	10.7	12
B	693	267.5	194
C	5,076	1,816.2	744
D	57	365.9	37
Total	5,853	Average 726.1	987

Figure 1. Columnar section of the rocks at the Ebensburg locality and their conodont yields.

All of the samples are dominated by the presence of platform (Pa) elements of *Streptognathodus elegantulus*. These are massively built elements that have the highest potential for survival from either mechanical or chemical attack during sedimentation, diagenesis, weathering, or laboratory processing. The platform elements of *S. elegantulus* are the most important ones for providing the necessary information for evaluating this outcrop.

Age and Correlation

As shown in Table 1, platform elements of *Streptognathodus,* all sufficiently complete to identify them as *S. elegantulus,* totally dominate the fauna. Among the Conemaugh marine units this condition is only true in the Ames marine zone and two local younger units in eastern Ohio. Unlike these two minor, local units, the Ames is a genuinely widespread rock body occurring in all five states where Conemaugh rocks crop out (Ohio, Pennsylvania, Maryland, West Virginia, and Kentucky). Its fauna is remarkably uniform throughout this region. Although *S. elegantulus* occurs in older units along with other species of *Streptognathodus,* this species in the Ames can be distinguished from those in all other Appalachian units by the ratio between the lengths of the carinae and the lengths of the platforms (Merrill and Wentland, 1986). Based on the nearly exclusive occurrence of this species in the Ames as well as the state of the carinae, it is easy to distinguish the Ames from all of the other marine units shown in Figure 2 of Brady and others (1985)—the Woods Run, Pine Creek, and Brush Creek. The conodont evidence demonstrates conclusively that the Ebensburg occurrence is essentially coeval with the type Ames in southern Ohio and elsewhere. Nearly identical occurrences of Ames conodonts have been described in western

Table 1. *Summary Conodont Distribution, All Ebensburg Samples*

	Platform elements	*Ramiform elements*	*Total*
Streptognathodus elegantulus	997	555	1,552
Streptognathodus sp(p.) platforms	2,106	—	2,106
Cavusgnathus lautus	6	—	6
Cavusgnathus merrilli	3	—	3
Hindeodus minutus	162	103	265
Diplognathodus cf. *ohioensis*	2	—	2
Aethotaxis cf. *douglasensis*	N/A	62	62
Idioprioniodus cf. *cornutus*	N/A	3	3
Ellisonia cf. *conflexa*	N/A	1	1
Hindeodellids	N/A	1,320	1,320
Indeterminable fragments	N/A	872	872
		Total	5,853

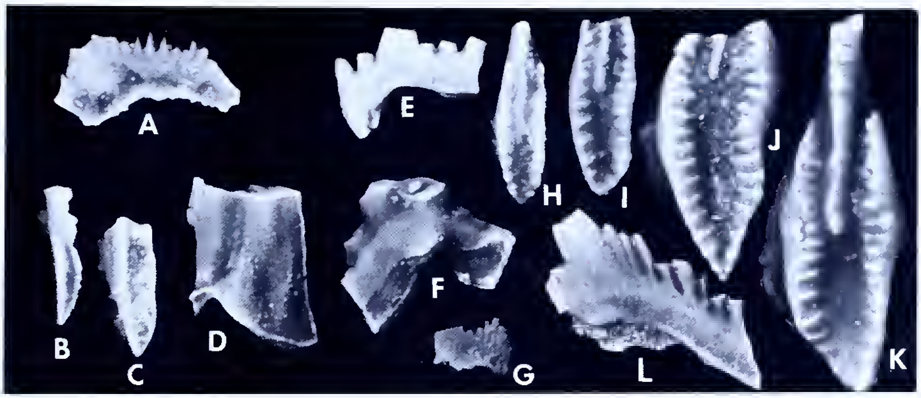


Figure 2. Photomicrographs of Ebensburg conodonts; all illustrations x40. All specimens are from sample C (Figure 1) except Figure 2K, which is from sample B. A. *Hindeodus* cf. *ellisoni* (Merrill), Pa element, Royal Ontario Museum (ROM) 45575. B. *Cavusgnathus lautus* Gunnell, dextral Pa element, ROM 45576. C. *Cavusgnathus merrilli* von Bitter, sinistral(?) Pa element, ROM 45577. D. *Idioprioniodus* cf. *cornutus* (Stauffer and Plummer), Ne element, ROM 45578. E. *Aethotaxis* cf. *douglasensis* (von Bitter), Sc element, ROM 45579. F. *Aethotaxis* cf. *douglasensis* (von Bitter), "X" element, ROM 45580. G. *Diplognathodus* cf. *ohioensis* (Merrill), Pa element, ROM 45581. H-K. *Streptognathodus elegantulus* Stauffer and Plummer, Pa elements, ROM 45582, 45583, 45584, and 45585, respectively. L. *Streptognathodus elegantulus* Stauffer and Plummer, Pb element, ROM 45586.

Maryland, only about 85 km (53 mi) from Ebensburg (Merrill and Lyons, 1987).

Paleoecology and Paleogeography

In many samples of Pennsylvanian marine rocks another conodont genus, *Cavusgnathus* (most common species *C. lautus*), occurs with *Streptognathodus* in varying ratios. It is generally accepted that *Cavusgnathus* was able to tolerate a greater range of salinities than *Streptognathodus,* and finding large numbers of cavusgnathoids usually indicates reduced salinities close to shore. For example, in the Ames in southern Ohio there is a prominent gradient in the ratios between the genera northward away from shore (Merrill, 1982). With so few cavusgnathoids, the Ebensburg locality shows no sign of reduced salinities, and the western Maryland material appears to be nearly as stenohaline (Merrill and Lyons, 1987). In part these conodont data conflict with opinions expressed by Brezinski (1983) and Saltsman (1986), who mapped molluscan biofacies in the Ames as being relatively nearshore. Brezinski (1983, Figure 1) placed the Ebensburg area essentially on the ancient Ames shoreline, calling for only noncalcareous shale containing a molluscan biofacies. In fact a significant limestone is present at Ebensburg, and the fauna is mixed brachiopodal-molluscan. These observations, along with the likelihood that one of the marine zones encountered in the Broad Top borehole may be Ames (Edmunds and Glover, 1986), suggest that Ebensburg was not that close to the easternmost limit of the Ames marine basin.

Summary and Conclusions

The Conemaugh locality at Ebensburg is of Virgilian age and can only be correlated (identified) with the Ames marine zone elsewhere within the Appalachian basin. Although biometrics have not been done on the streptognathodontid platform elements, it is certain that they would precisely confirm this age assignment. The fauna belongs entirely to the *Streptognathodus* biofacies, indicating that the interval sampled was deposited under conditions of normal salinity. Although these situations could occur under certain conditions in nearshore environments, other nearshore Ames localities elsewhere in the basin show strong increases in the proportion of *Cavusgnathus,* an abnormal salinity indicator, and the conclusion that this locality was a substantial distance from shore seems well supported.

Acknowledgements

The author thanks P. C. Lyons for calling his attention to the Brady and others (1985) note. Field work for this collecting was supported by U.S. Geological Survey grant 14-08-0001-G1270.

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NEW PUBLICATIONS

Oil and Gas Developments in Pennsylvania in 1986

The 1986 annual report on oil and gas developments in Pennsylvania is now available for sale to the public. The new report, like its predecessors, is packed with information concerning oil and gas well drilling activities, production and reserves, drilling costs and commodity prices, and exploratory and development highlights. For example, industry reported 2,951 wells drilled in Pennsylvania in 1986, a 37 percent decrease from the previous year. Oil production decreased 22 percent to 3,783,087 barrels in 1986, whereas gas production increased 6 percent to 159,889 million cubic feet. Oil reserves decreased 7 percent to 49,223,000 barrels, but gas reserves increased 2 percent to 2,053,536 million cubic feet. The average price for a barrel of crude oil in 1986 was $15.66, and the average price for a thousand cubic feet of gas was $2.50. It cost about $40 per foot to drill an 800-foot-deep oil well in Venango County and about $65 per foot to drill an 8,000-foot-deep gas well in Westmoreland County. Over 100 exploratory wells were reported completed in 1986, resulting in the discovery of 3 new fields and 18 new pools. But perhaps the most exciting exploratory activity reported was the completion of a 10,500-foot-deep well in the Triassic-Jurassic rocks of the Newark basin north of Philadelphia.

The annual report also includes information on enhanced oil recovery, gas storage, deep versus shallow drilling, geophysical activity, and activities on state lands. Fifty-three pages of the report are devoted to the deep-well summary table. There are also sections dealing with projects in progress in the Oil and Gas Geology Division for those interested in keeping up with the latest research news.

The new report, authored by John A. Harper, is Progress Report 200, **Oil and Gas Developments in Pennsylvania in 1986.** Copies of the report are available from the State Book Store, P. O. Box 1365, Harrisburg, PA 17105 for $2.50 plus 15¢ sales tax for Pennsylvania residents. All orders must be prepaid; make checks payable to *Commonwealth of Pennsylvania*.

French Creek State Park Guide

The Pennsylvania Geological Survey has recently issued a revised and expanded version of Park Guide 6, **French Creek State Park, Berks and Chester Counties**. The authors, J. D. Inners of the Pennsylvania Survey, and W. B. Fergusson of Villanova University, describe the general geology of the park and relate the rocks and landscape to the development of the early iron-mining industry in the region.

Park Guide 6 is available at no charge at French Creek State Park, or upon request from the Pennsylvania Geological Survey, P. O. Box 2357, Harrisburg, PA 17120.

17 NEW COUNTY TOPOGRAPHIC MAPS ISSUED

County map coverage at 1:50,000 scale has been expanded to include 17 more counties in Pennsylvania. The total number of county "topo" maps now available is 59. These maps are produced as part of the ongoing cooperative program of mapping Pennsylvania conducted by the Pennsylvania Geological Survey and the U.S. Geological Survey.

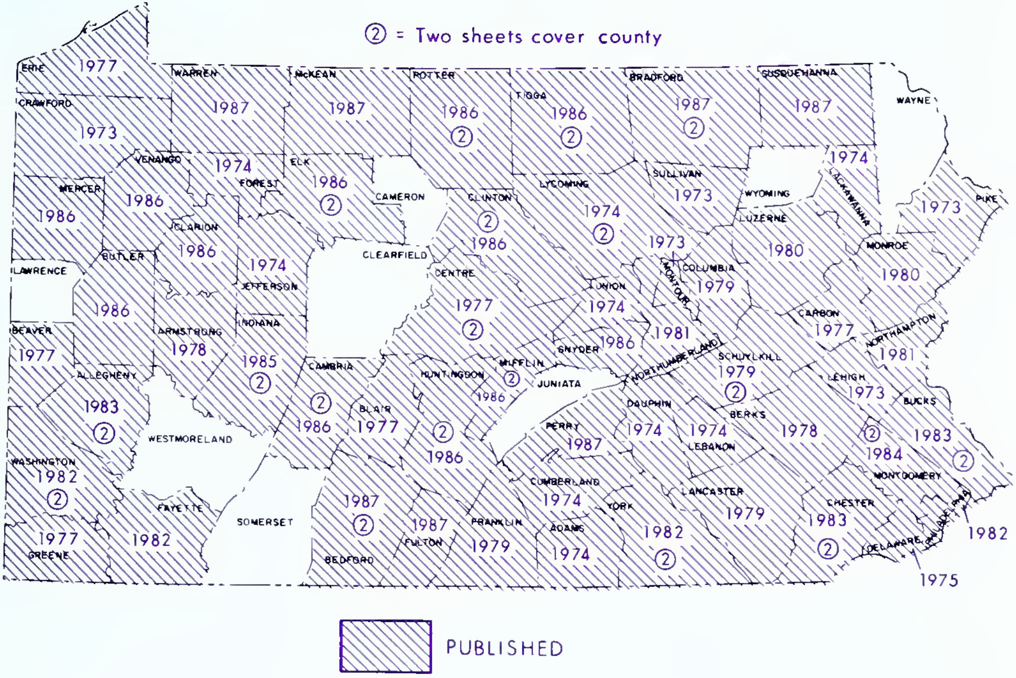
Topographic maps show landforms through the use of contours. They also show all existing surface features, including rivers, streams, and lakes, as well as man-made features, including trails, railroads, and buildings. Political boundaries shown are township, borough, and city lines. Contours are printed in brown, man-made features in black, major roads and urban areas in red, forested areas in green, water features in blue, and political boundaries in orange.

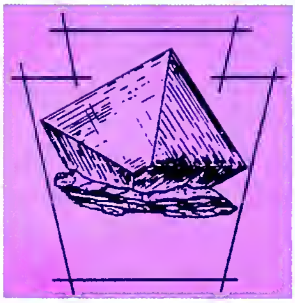
County topographic maps recently published include Bradford (east and west), Bedford (north and south), Butler, Cambria, Clarion, Elk (east and west), Fulton, Huntingdon (north and south), McKean, Mifflin (north and south), Perry (east and west), Potter (north and south), Snyder, Susquehanna, Tioga (east and west), Venango, and Warren. The index map below shows all county maps available.

These maps may be purchased for $4.50 per sheet by writing to the U.S. Geological Survey, Map Distribution, Box 25286, Federal Center, Denver, CO 80225. Prepayment is required; make checks payable to *U.S.G.S.* A $1.00 handling charge should be included on orders less than $10.00. Lehigh County (Pennsylvania Geological Survey Map 39) is available from the State Book Store, P. O. Box 1365, Harrisburg, PA 17105. The price is $1.80, plus 11¢ sales tax for Pennsylvania residents. Prepayment is required; make checks payable to *Commonwealth of Pennsylvania*.

For more information, contact the Pennsylvania Geological Survey library, the National Cartographic Information Center (NCIC) Affiliate, telephone 717-783-8077; or contact NCIC Headquarters at the U.S. Geological Survey, telephone 1-800-USA-MAPS.

1:50,000-SCALE COUNTY TOPOGRAPHIC MAPS





EARTH SCIENCE TEACHERS' CORNER

by Dean Steinhart, Director
Office of Environmental Education
Pennsylvania Department of Education

A major objective in the teaching of science is to connect the various concepts of "science" into a practical base of knowledge that has application in the real world. This connectedness promotes integration of various disciplines, including the physical and biological sciences, into the conceptual wisdom of natural science. The teaching of earth science usually incorporates the hydrologic cycle, the work of surface water, groundwater, oceans, and glaciers. Closely related to these topics of study are the concepts of erosion, sedimentation, and the creation of various landforms and topographic features. Connecting these concepts into an understanding of the "watershed" and the human impact on the management of natural resources is the focus of a packet of curriculum activities available through the Office of Environmental Education. Integral to the use of these activities is a topographic map that is used to complete the various exercises in the 7th- through 12th-grade activities.

The exercises featured are for K–12 instruction and offer hands-on opportunity for each student. These materials were written and tested by teachers and became part of the Environmental Education Week packet that was mailed to all Pennsylvania school districts in October 1987.

These activities will help teachers demonstrate the use of topographic maps and the identification of map symbols. Each exercise is set up with a goal statement, procedure, and, where necessary, background information. Habitats are emphasized in the watershed, and students will have an opportunity to participate in a debate about development in the watershed. There is an opportunity for students to look at water quality and acid deposition within the activity framework.

Teachers may obtain the packets by writing to the Department of Education, Office of Environmental Education, 333 Market Street, Harrisburg, PA 17126.

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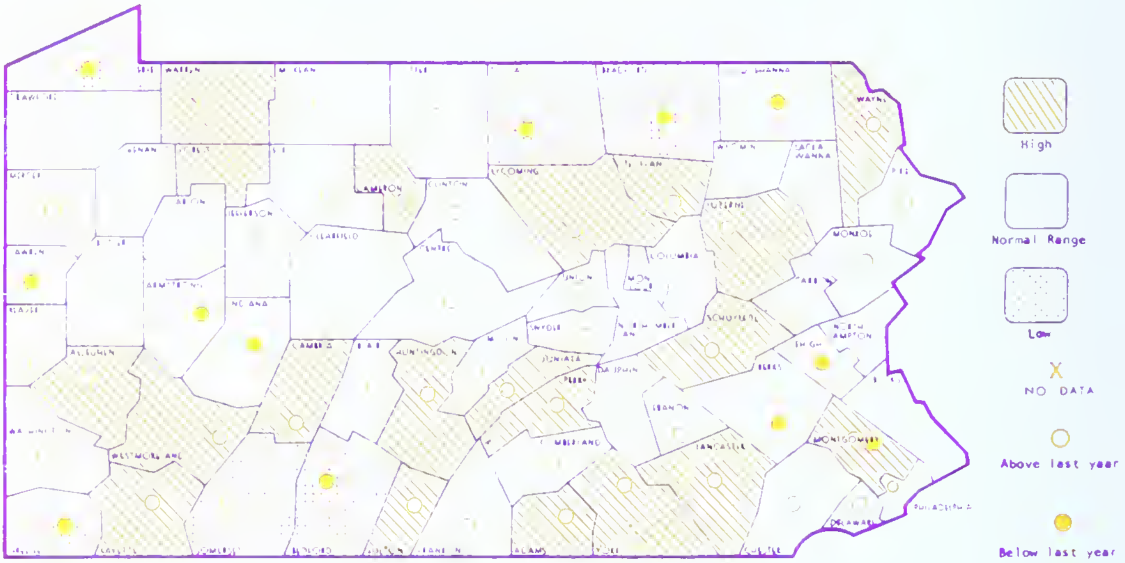
GROUNDWATER-RESOURCE MAPPING

GROUNDWATER LEVELS
FOR
FEBRUARY 1988



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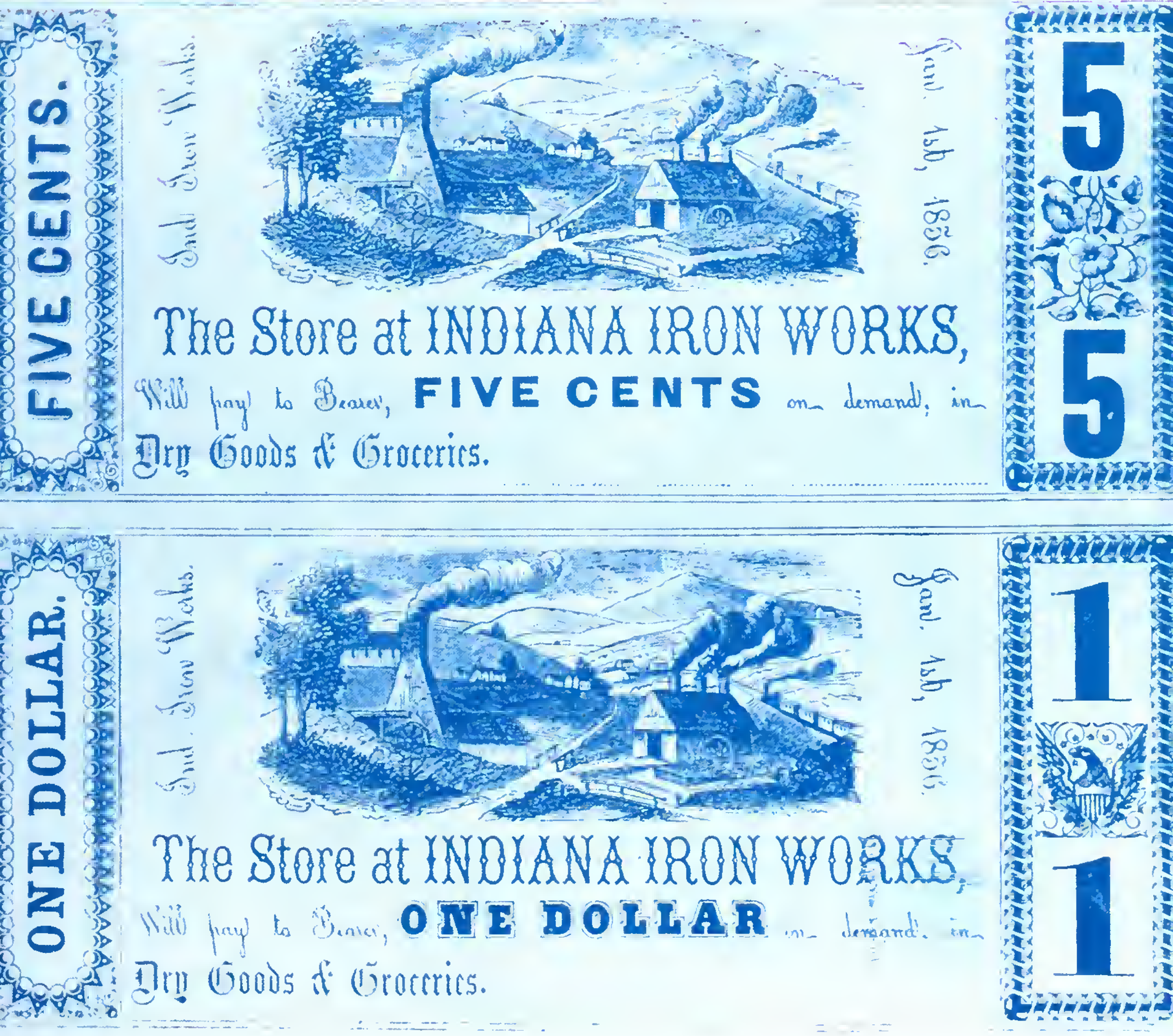

FIVE CENTS.

Ind. Iron Works.

Jan. 1st, 1856.

The Store at INDIANA IRON WORKS,
Will pay to Bearer, **FIVE CENTS** on demand, in
Dry Goods & Groceries.

5
5

ONE DOLLAR.

Ind. Iron Works.

Jan. 1st, 1856.

The Store at INDIANA IRON WORKS,
Will pay to Bearer, **ONE DOLLAR** on demand, in
Dry Goods & Groceries.

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THE PENNSYLVANIA GEOLOGICAL SURVEY

VOL. 19/3

COMMONWEALTH OF PENNSYLVANIA
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ON THE COVER: Five-cent and one-dollar notes issued by the Indiana Iron Works in the mid-nineteenth century for redemption at the company store (see article on page 2). Color is similar to that on the original notes. Notes are shown at 92 percent of their actual size. Photograph by Paul Farmer.

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Editor, Christine M. Dodge

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VOL. 19, NO. 3 **JUNE 1988**

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The Risks of Driving Through Geology

Drivers on Pennsylvania highways need to be aware of the ever present danger of rockfalls, landslides, and other geologic hazards to their safe passage. In this issue we feature a detailed discussion of a recent slide that occurred so suddenly that four vehicles were damaged; luckily no lives were lost. But such is not always the case. In midwinter one life was lost and another person injured on New York State's Governor Thomas E. Dewey Thruway from a rockfall.

Highway design needs to take into account the geology of the area over which traffic is to pass. The roadcuts created by highway construction are important to geologists because they show us the rocks normally hidden by soil or surficial materials. But by "cutting" into the rocks the natural systems are interrupted, and inexorably nature seeks to return to natural slopes. The strength of the rock masses progressively deteriorates. As the roads age we can see and feel the effects through the uneven surface, visible cracks, and potholes that seem to occur overnight.

As the roads age visibly so do the roadcuts, but this weathering is invisible to the passerby. By serendipity the area of the Chulasky rockslide had been examined in detail nearly three decades ago by a Survey geologist. Thus our modern examination of the now-deteriorated rock was aided by the prior description in determining the exact rock layer along which the slide occurred.

We can predict from these examinations that rockfalls and landslides will continue to occur, and with probably greater frequency now that our interstate highway system and system of freeways are several decades old. Thus driving through the geology of Pennsylvania takes on an added consideration, and that is of greater caution while traversing steep roadcuts. The new highways and new roadcuts being produced and being described by geologists will be the site of future rockfalls and should be passed with great caution.

Donald M. Hoskins

Donald M. Hoskins
State Geologist

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DOCUMENTS SECTION

IRON-MINING STORE SCRIP IN PENNSYLVANIA

by G. Robert Ganis
Tethys Consultants, Inc., Harrisburg, PA

The early manufacture of pig iron in America was a localized industry. Wherever iron ore, fuel, limestone, and power were found in reasonable proximity to each other, small iron furnaces flourished. Because of their remoteness from civilization, these furnaces became the centers of feudal plantations in which the workers were dependent on the paternalistic benevolence of the resident ironmaster or the more remote iron company. Examples of the few restored or fortuitously preserved Pennsylvania iron plantations include Hopewell in Berks County (Inners and Fergusson, 1987) and Mount Etna in Blair County (Inners, 1986).

Many of the companies that controlled iron plantations paid the workers' wages in scrip that could only be redeemed in the company stores, or "pluck me's" (Figure 1). Although such stores were vital to supplying the necessities of life to the inhabitants of the local community, the issuance of scrip, the "liberal" use of charge accounts,

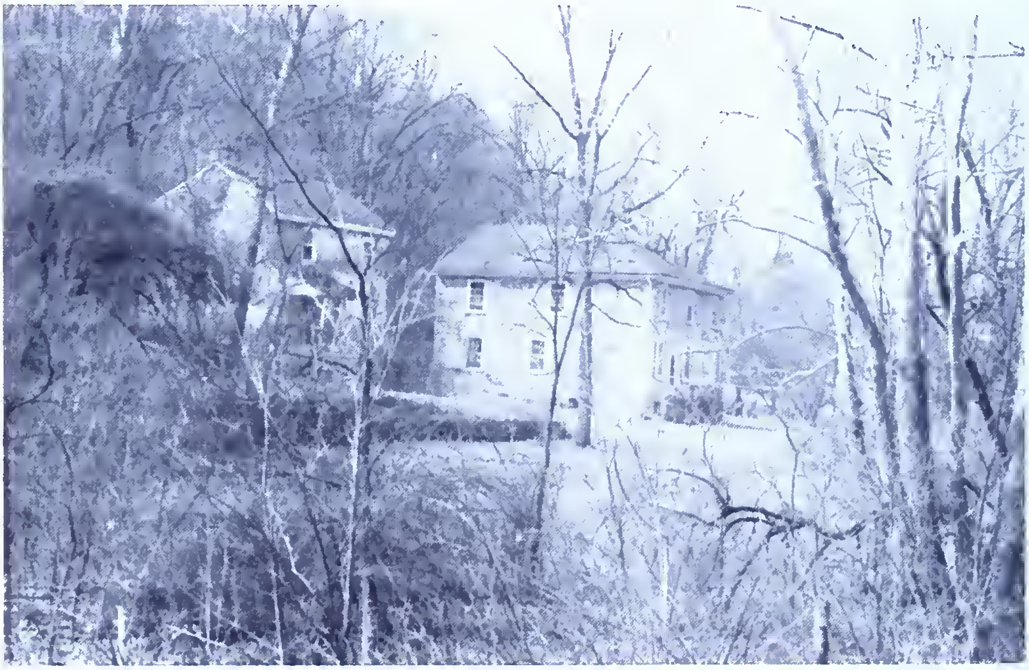

Photograph by Jon D. Inners

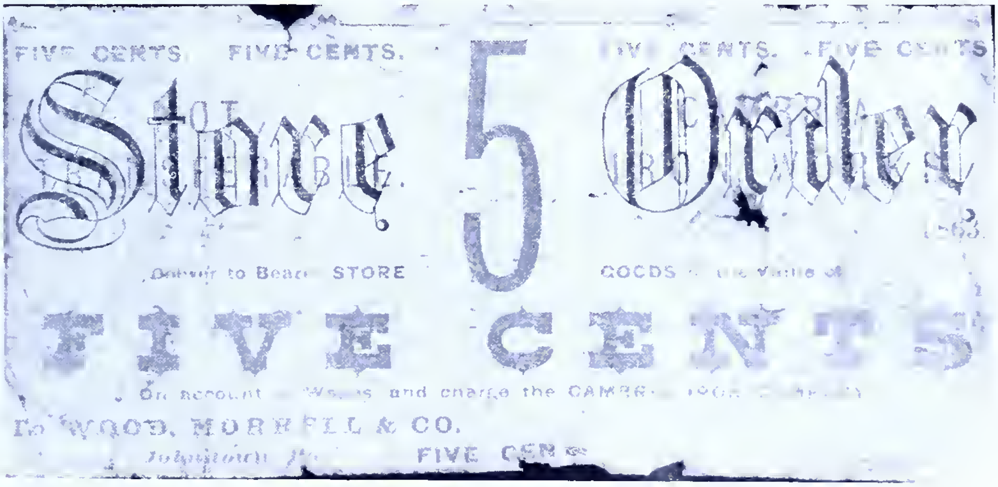
Figure 1. Manager's house (left) and office-company store (right) at Mount Etna iron furnace in Blair County.

and high prices meant that the individual worker almost invariably "owed his soul to the company store." (Charging inflated prices in the stores also helped to boost the thin profit margins of the iron manufacturers.) A less sinister effect of the use of scrip was to allow companies to "weather" the periodic depressions and currency shortages that so frequently disrupted nineteenth-century American industry. These money shortages were brought on in part by the hoarding of gold and silver following major economic and political upheavals.

Some of this old iron-furnace scrip has survived to come within the purview of the modern numismatist. Hoober (1985) lists extant scrip of 23 different companies or furnaces. Although most notes are rare, it is still possible to obtain exquisite material from mail-order dealers and at coin-and-currency shows.

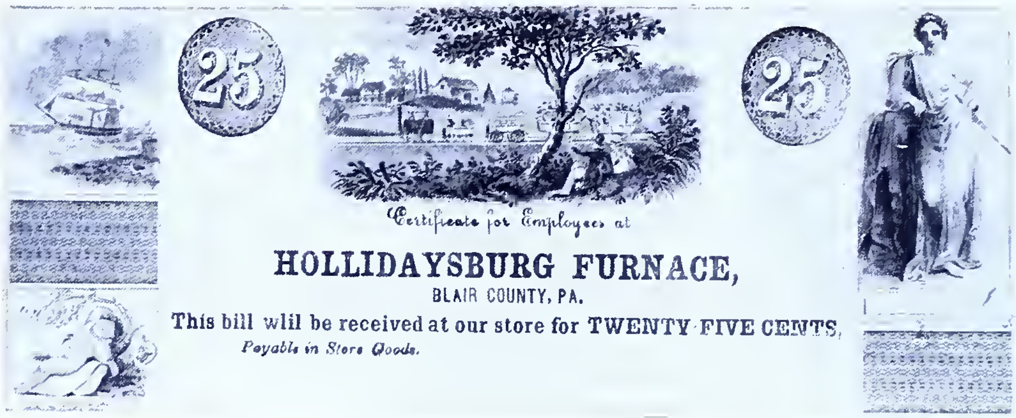
An example of Pennsylvania scrip is the "five-cent" note issued by the Cambria Iron Company (Figure 2) of Leathercracker Cove at Henrietta P.O. in Blair County. At the Henrietta ore bank, limonitic lump ore was mined from weathered limestone of Formation No. II (Platt, 1881), the Cambro-Ordovician limestones, undifferentiated, of modern usage. The Hollidaysburg Furnace, which used the Henrietta ores, also issued scrip (Figure 3).

Company scrip was commonly printed by stationers, usually on thin rice paper sheets. Vignettes were often taken from catalogs, and the complexity and originality of the notes varied according to the budget for printing and the need for anticounterfeiting measures. Sheets of the Allegheny Furnace iron works (Figure 4) and the In-



Photograph by Paul Farmer

Figure 2. Cambria Iron Company scrip from Henrietta ore banks. The note is shown at 75 percent of its actual size and was originally printed in red and blue.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Certificate for Employees at

HOLLIDAYSBURG FURNACE,

BLAIR COUNTY, PA.

This bill will be received at our store for TWENTY FIVE CENTS,

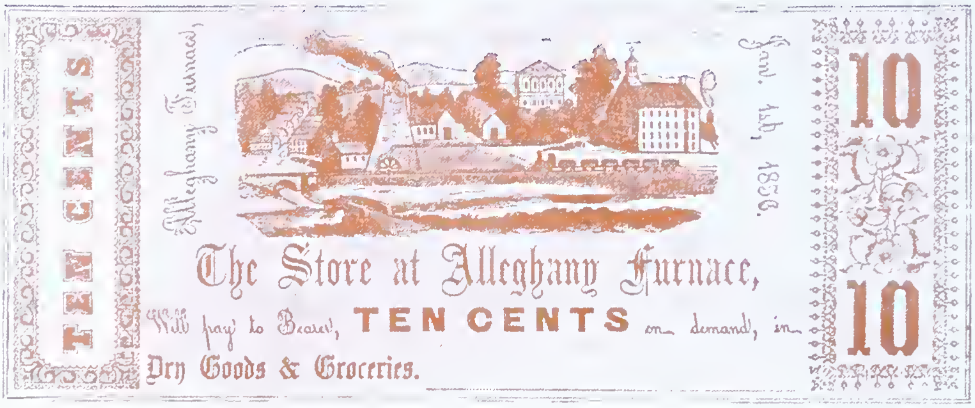
Payable in Store Goods.

Photograph by Paul Farmer

Figure 3. Scrip from Hollidaysburg Furnace. The note is shown at 73 percent of its actual size and was originally printed in black.

diana Iron Works (cover photo) appear to have been made by the same printer. The vignettes on the scrip of these two furnaces may provide rough sketches of their appearance.

Several factors contributed to the demise of small pig-iron operations in the late nineteenth century. The preferred use of steel over iron, particularly in rails, was the greatest blow. Discovery of the great iron ranges of the Lake Superior region in 1844 and opening of the Sault Sainte Marie Canal in 1855, followed by development of the Bessemer converter in 1856 (Bateman, 1950; Hogan, 1971), gave rise to a national dimension for steelmaking and the marketing of steel in America. When the maturation of the railroad system in America made transportation of iron and steel products feasible throughout the country, the small, local blast furnaces dependent on low-grade iron deposits were overwhelmed.


TEN CENTS

Alleghany Furnace,

Jan. 1st, 1856.

The Store at Alleghany Furnace,

Will pay to Bearer, TEN CENTS on demand, in

Dry Goods & Groceries.

10

10

Photograph by Paul Farmer

Figure 4. Scrip from Allegheny Furnace. Color is similar to that on the original note. Note is shown at 70 percent of its actual size.

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NEW USGS PUBLICATIONS

by Thomas M. Berg
Pennsylvania Geological Survey

Two detailed 1:24,000-scale bedrock geologic maps in the Great Valley area of Berks and Lehigh Counties have recently been released by the U.S. Geological Survey. The **Geologic Map of the Topton Quadrangle, Lehigh and Berks Counties, Pennsylvania** (Geologic Quadrangle Map GQ–1609), by Avery Ala Drake, Jr., shows the distribution of complexly folded and faulted Cambrian and Ordovician rocks. The bedrock units shown on the map are parts of three distinctive assemblages of marine sedimentary rocks which are called the Schuylkill sequence, the Lehigh Valley sequence, and the Hamburg klippe sequence. The formations and members within these sequences were deformed during two major mountain-building events called the *Taconic orogeny* and the *Alleghanian orogeny*. Major thrust, tear, and high-angle faults are shown, along with the locations of folds and planar and linear features. Two structure sections are printed with the map, as is a brief description of the stratigraphy and structure of the quadrangle.

The **Geologic Map of the Hamburg Quadrangle, Schuylkill and Berks Counties, Pennsylvania** (GQ–1637), by Gary G. Lash, portrays a similar complex of Cambrian, Ordovician, and Silurian rocks. The northwest portion of this quadrangle includes part of the Ridge and Valley province of Pennsylvania. Faults, shear zones, folds, and planar and linear features are shown on the map; these structural features are elaborated in four structure sections and a number of stereographic projections. A brief text contains an explanation of the geologic structure as well as the depositional environments of all of the sedimentary rock units, which range from deep marine basins to braided rivers.

Both of these new maps are significantly different from earlier renditions of the bedrock geology, as shown on the 1980 *Geologic Map of Pennsylvania* (Pennsylvania Geological Survey Map 1). Drake and Lash have refined and sharpened our understanding of Lower Paleozoic stratigraphy of the Great Valley area, and have greatly clarified the Taconic and Alleghanian structural framework. Geologists, consultants, and engineers will find the maps valuable for understanding the bedrock of these areas. Recent bedrock mapping in adjacent areas includes the **Geologic Map of the Kutztown Quadrangle, Berks and Lehigh Counties, Pennsylvania** (GQ-1577), by G. G. Lash, and **Geologic Map of the Slatedale Quadrangle, Lehigh and Carbon Counties, Pennsylvania** (GQ-1598), by Peter T. Lyttle, G. G. Lash, and Jack B. Epstein.

A new 1:250,000-scale geologic map published by the U.S. Geological Survey includes a large part of southeastern Pennsylvania. The **Geologic Map of the Newark 1° x 2° Quadrangle, New Jersey, Pennsylvania, and New York** (Miscellaneous Geologic Investigations Map I-1715), by P. T. Lyttle and J. B. Epstein, shows a version of the bedrock geology of the Commonwealth between 40° and 41° latitude north, and 74° and 76° longitude west. In the majority of this area, the new map is identical to the 1980 *Geologic Map of Pennsylvania*, but there are significant differences, particularly in the Great Valley, in parts of the Mesozoic Lowlands, and in the Piedmont Uplands. Many of the differences are real improvements, some of the differences are simply based on opinion, and some differences are omissions. Comparing the 1980 *Geologic Map of Pennsylvania* with the Newark 1° x 2° quadrangle is an interesting lesson which teaches that most geologic maps covering large areas are "a moment in time" and are likely to be revised later. A very important aspect of the new map is that it contains proposed new rock nomenclature for the metamorphic rocks of the Piedmont. Additionally, structure sections that accompany the map provide new interpretations which will spark further thought and more accurate future investigations.

The new 1:24,000-scale GQ maps each cost $3.60, and the 1:250,000-scale Newark map costs $6.70. The maps may be purchased from Map Distribution Section, U.S. Geological Survey, Box 25286, Federal Center, Denver, CO 80225. Prepayment is required; make checks payable to *U.S.G.S.* For orders under $10.00, there is a $1.00 charge for postage and handling.

"Danger—Falling Rocks": The Chulasky Rockslide

by Jon D. Inners, Pennsylvania Geological Survey,
and Duane D. Braun and Norman M. Gillmeister,
Bloomsburg University

"Fallen Rock Zone" and "Danger—Falling Rocks" are familiar signs to motorists on highways in the folded Appalachians of central and eastern Pennsylvania. Familiarity in this case does breed contempt, or at least disregard; many a driver has been rudely jarred from reverie by running over a fist-sized chunk of rock on the roadway or, even worse, catching a "gooney" on the hood or windshield. Even a single rock hurtling off a 75-foot-high cut slope can have serious, even fatal, effects on passersby. Yet how much more devastating if a "chunk of mountain" weighing many thousands of tons comes crashing onto the highway! Twice in the last two years such massive rockslides have obstructed traffic on major highways in the North Branch Susquehanna River basin. Both occurred in March—probably the most "propitious" month for seasonal landslides; both took place in areas where rock strata dip out of mountainsides or hillsides toward roadways; and both resulted in property damage, but no fatalities. (Will we be so lucky the next time?) Braun and others (1987) described the first of these rockslides—that on Penobscot Mountain in Luzerne County. The second is the subject of the present article.

****

At 11:15 p.m. on Sunday, March 1, 1987, several thousand cubic yards of rock slid onto rain-slicked U.S. Route 11 approximately 2 miles west of Danville in central Pennsylvania. Because of poor visibility and the suddenness of the event, four vehicles—two tractor-trailers and two automobiles—hit the slide mass. Debris from the slide covered all four lanes of Route 11, but did not reach the railroad tracks that lie between the highway and the North Branch Susquehanna River. It took Pennsylvania Department of Transportation (PennDOT) crews 5 days, working 8 to 10 hours a day, to completely remove the slide mass. All four lanes were finally opened to traffic in mid-afternoon on Friday, March 6. As with most highway slope failures, however, removal of the rock debris was only the first step in the difficult task of stabilizing the slope. Remedial sculpting of the slide area in December 1987 removed a precarious overhang and reduced the threat of future slides at this particular location.

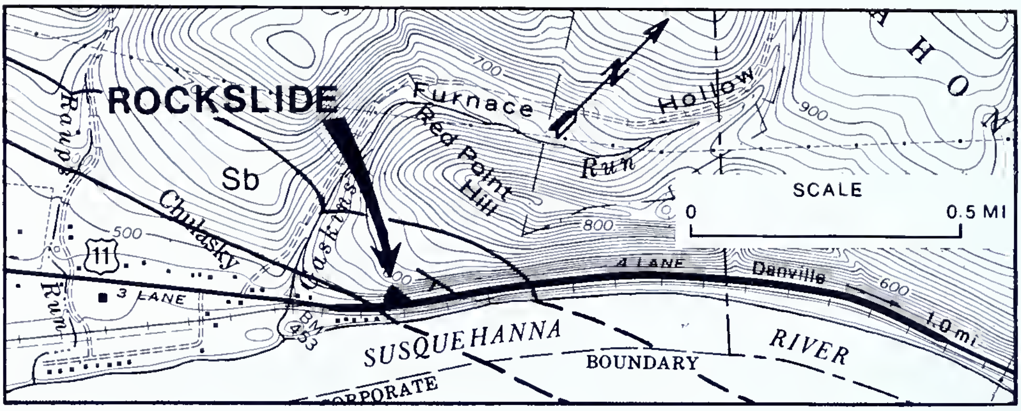


Figure 1. Location map showing the outcrop of the Bloomsburg Formation (Sb) in the vicinity of Chulasky. Note that the rock strata dip to the southeast.

The rockslide took place at the southwest end of a long cut slope on the south side of Red Point Hill at Chulasky, Northumberland County (40°57′22″N/76°39′44″W, Riverside quadrangle; Figure 1). For a distance of more than a mile northeast of "Red Point," a four-lane highway and a single-track railroad grade are squeezed into a narrow space between a loop of the North Branch and Montour Ridge. The transportation corridor trends obliquely across the "strike" of the southeast-dipping bedrock units forming Montour Ridge and its southern foothills. While the highway has followed its present course for more than a century, the last major widening (to four lanes) took place in the mid-1950's. As a result of this construction, the roadway was left with a narrow shoulder adjacent to the slope and a serious rockfall hazard. On February 24, 1970, PennDOT personnel using a crane "surgically" removed a 30- to 35-cubic-yard mudstone block bounded by open joint cracks in the same areas as the 1987 slide. Later that winter, a new ½:1 pre-split cut slope up to 100 feet high was constructed for a distance of 0.4 mile along the northwest side of the highway. This redesigned slope created a 23-foot safety zone between the hillside and the edge of the highway (Roads and Streets, 1971), but at the same time exacerbated the undercutting of the natural hillslope.

The slope failure of March 1987 occurred in thick-bedded, grayish-red (5R4/2) silty mudstone of the upper part of the Bloomsburg Formation. According to the measured section of Hoskins (1961), the beds involved in the landslide lie about 90 feet stratigraphically below the base of the sandy Moyer Ridge Member (Figure 2).

At the site of the failure, the main structural discontinuities in the Bloomsburg mudstones are bedding and three sets of systematic,

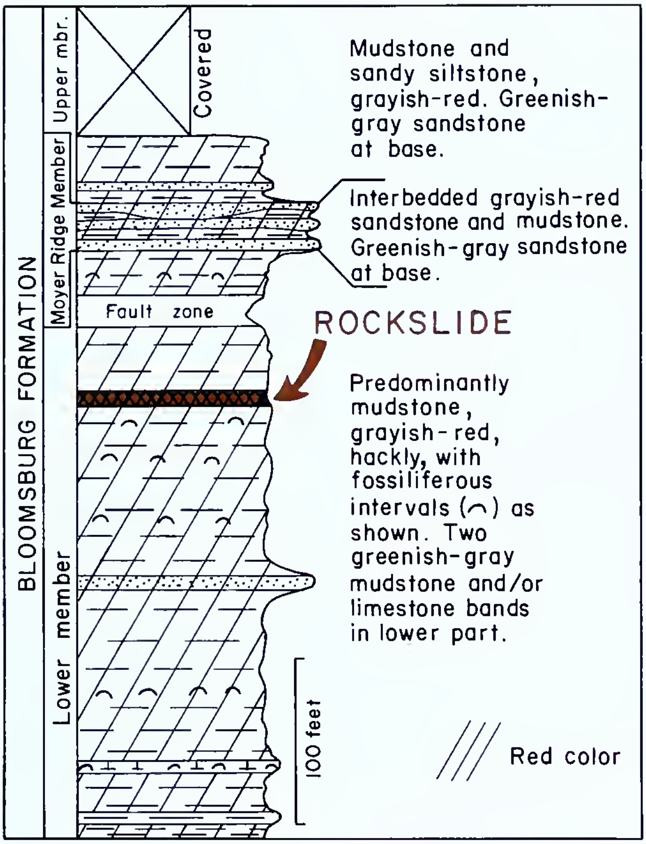
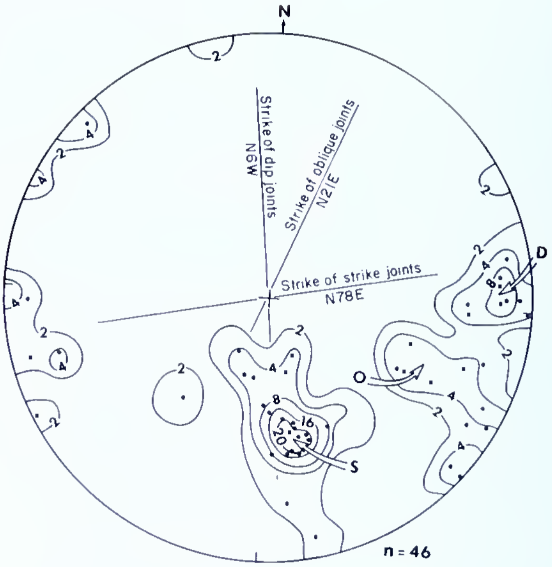

BLOOMSBURG FORMATION
Upper mbr.
Moyer Ridge Member
Lower member
Covered
Fault zone
Mudstone and sandy siltstone, grayish-red. Greenish-gray sandstone at base.
Interbedded grayish-red sandstone and mudstone. Greenish-gray sandstone at base.
ROCKSLIDE
Predominantly mudstone, grayish-red, hackly, with fossiliferous intervals (⌒) as shown. Two greenish-gray mudstone and/or limestone bands in lower part.
100 feet
Red color

Figure 2. Stratigraphic section of the Bloomsburg Formation, showing the position of beds involved in the Chulasky rockslide (after Hoskins, 1961).

planar fractures (joints) (Figure 3). The bedding-plane partings, which dip moderately to the southeast, are of two types. Most partings mark the boundaries between mudstone units, are relatively smooth, and have 0.5- to 2-foot spacings on average. Less common (spaced at +10-foot intervals) are extremely smooth partings at the top and bottom of thin siltstone beds. Of the dominant fracture sets, strike and oblique joints tend to be moderately discontinuous and relatively smooth, whereas dip joints are generally very discontinuous and rough. Northwest-dipping strike joints that are orthogonal to bedding are the most common fractures; these are typically spaced 0.5 to 2 feet apart, but may repeat at 1- to 2-inch intervals locally.

The slide mass was 57 to 135 feet wide, up to 19 feet thick, and 150 feet long and had a total volume of about 5,000 cubic yards. Since the failure involved intact bedrock, it is classified as a rock block slide (Varnes, 1978). The bounding surfaces of the slide were a pair of smooth, southeast-dipping mudstone-siltstone bedding partings (above and below a 1-inch-thick siltstone bed) that served as the slide surface; a smooth northwest-dipping oblique joint in the west corner; a ragged subvertical dip joint on the extreme southwest side; and

Figure 3. Stereogram (equal-area lower hemisphere projection) of poles to joints in the Bloomsburg Formation at the site of the rockslide. Arrows indicate strike (S), dip (D), and oblique (O) joint sets. Contours are at 2, 4, 8, 16, and 20 percent per 1-percent area.



strike joints along a kink fold at the apex of the head scarp (Figures 4 and 5). The southeast side was the open face of the roadcut. The slide surface stepped down slightly from the top to the bottom of the thin siltstone bed in the northeast part of the slide area (Figure 5). Because the pre-split slope cuts obliquely across the strike of bedding, the slide mass actually rotated about 40 degrees to the southeast toward its unbound side as it moved off the slope.

Like other recent roadcut rockslides in the region (e.g., Allenwood and Nanticoke), the Chulasky slide was probably triggered by high cleftwater pressures developed in the slide mass after heavy rain-

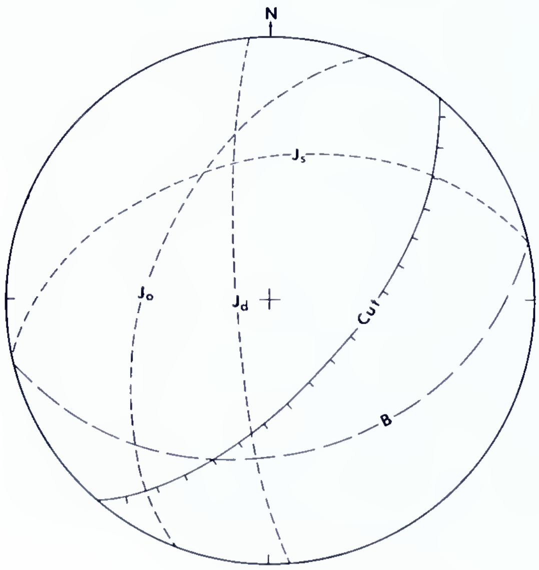


Figure 4. Stereogram (equal-area lower hemisphere projection) of major discontinuity surfaces of the rockslide. Bedding: B, N80E/-40SE (failure surface). Joints: J_s (strike), N78E/45NW; J_d (dip), N6W/80W; J_o (oblique), N21E/-52NW. The cut face shown (N40E at ½ to 1, or 63 degrees) is the design cut slope prior to failure.

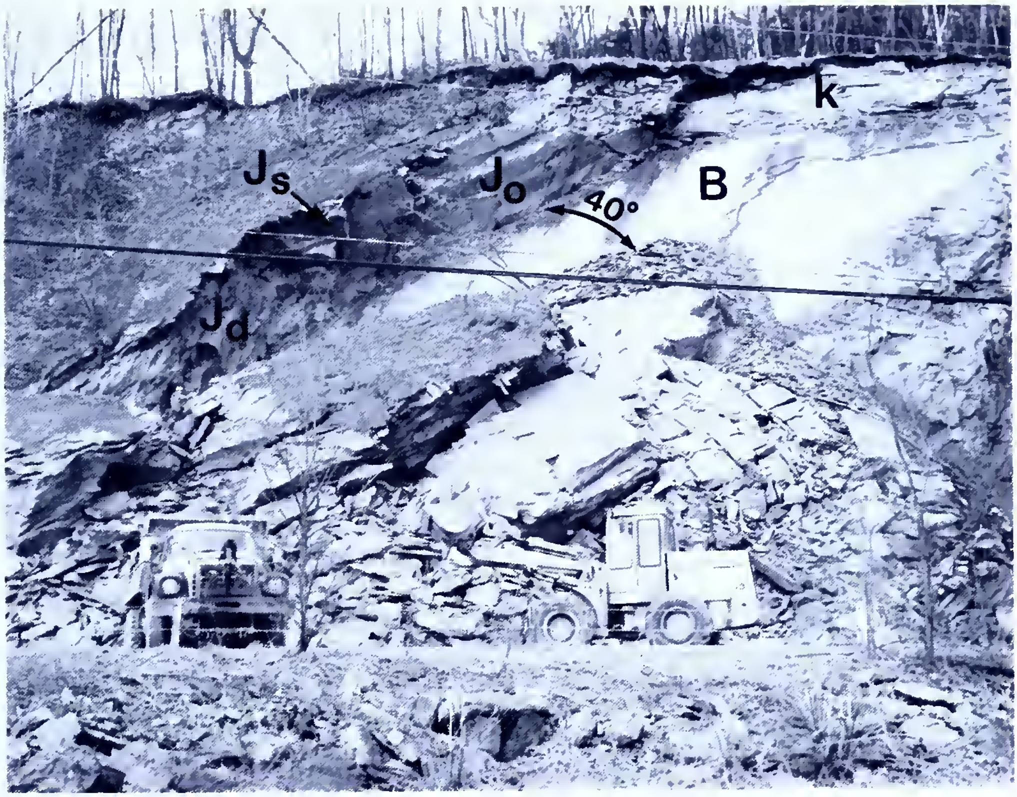


Figure 5. The Chulasky rockslide during cleanup operations, showing the major discontinuities (B, bedding; J_s, strike joints; J_d, dip joints; J_o, oblique joints; k, kink fold). Note the 40-degree clockwise rotation of the slide mass.

fall, ground thaw, and/or significant snowmelt (Inners and Wilshusen, 1986; Inners and others, 1987; Braun and others, 1987; Wilshusen and others, 1987). The immediate cause of failure was probably high cleft-water pressure on the smooth mudstone-siltstone bedding parting, combined with low tensile strength along the bounding joints. Since the only precipitation events recorded at the Williamsport weather station (24 miles to the north-northwest) in the 2 weeks before the failure at Chulasky were 0.6 inch of rain on March 1 and 4 inches of snow (water equivalent 0.28 inch) on February 23 (National Oceanic and Atmospheric Administration, 1987), it appears that precipitation in itself was insufficient to cause the slide. Of greater importance in increasing the water pressure along the failure surface may have been the thawing of ground frost and the melting of a heavy snowpack that reached a maximum of at least 22 inches on January 23 and had melted to a trace by February 26.

Because the failure of March 1 left large overhangs at the apex and in the west corner (see Figure 5), PennDOT carried out a controlled blast on December 8, 1987, which removed approximately

2,000 cubic yards of rock from these areas. Sufficient blasting compound was used to reduce the mudstone to cobble-size fragments, the largest of which were about 5 inches in maximum dimension. The blast formed an apron of material that completely covered the shoulder and the innermost lane of U.S. Route 11. Cleanup operations were completed on the following day, and the repaired slope now appears to be stable.

The authors thank Jake Schreck and Paul Solomon of PennDOT District 3-0 for information used in preparing this article.

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The Pennsylvania Academy of Science Includes Geoscience

A newsletter, journal, annual meetings at which there are presentations of scientific knowledge, a series of nearly a dozen hardcover publications—these are the tangible benefits to members of the Pennsylvania Academy of Science. Founded in 1924 to unite Pennsylvania scientists into one organization that could effectively advance science in Pennsylvania and the scientific spirit, the Academy now numbers over 800 members. Scientists from all regions of the Commonwealth and from all disciplines have banded together to expand the Academy from the 40 scientists who gathered in 1925 for the first annual meeting and exchange of information to the present organization, which attracts several hundred members to annual meetings and which sponsors a junior academy for young scientists numbering in the thousands.

Over the years, membership has been open to all scientists and those holding an interest in science. Membership of geoscientists continues to be encouraged, and evidence of membership of those having an interest in geology and earth science is apparent each year in the issues of the *Proceedings* and the annual meeting program listings. However, more support from this quarter is needed to provide a true balance in the Academy of those who have an interest in the geosciences.

The Academy welcomes geologists, hydrogeologists, and earth scientists to join in membership with other scientists of Pennsylvania, all of whom have the same objectives: to encourage scientific research and publication; to disseminate scientific knowledge; to form new fellowships with scientists and grow professionally; to extend the information about the Commonwealth to those outside its borders, both domestic and international; and to support the activities of young scientists as their interests in various fields mature.

The Proceedings of the Pennsylvania Academy of Science offers a unique format for publishing the results of scientific research. Published twice per year, the refereed journal is acknowledged by institutions and libraries throughout the world as one of high quality. The Academy urges all of its members to consider publication in the *Proceedings,* and those in the geoscience community are also most welcome to submit manuscripts for publication, one benefit that accompanies membership.

In recent years, the Academy has published a series of books on coal, energy, hazardous wastes, and threatened species, among others. The Academy provides these books at discount to members and in 1988 has offered a free book with new memberships. To receive the details of the book offer and a membership application, contact any officer of the Academy or write to Dr. Howard Pitkow, Pennsylvania College of Podiatric Medicine, 8th and Race Streets, Philadelphia, PA 19107.

The Academy encourages your participation as well as support. Make 1988 your membership year and help the Academy continue its service to Pennsylvania.

REMINDER!
1988 FIELD CONFERENCE
October 6–8

The 53rd Annual Field Conference of Pennsylvania Geologists will meet in Hazleton, Pennsylvania, the "Mountain City." The bedrock and surficial geology of the North Branch Susquehanna River lowland and the Eastern Middle Anthracite field will be emphasized. Of particular geologic interest are planned stops at the great Woodfordian frontal kame near Berwick, the spectacular Council Cup Scenic Overlook at Wapwallopen, exposures of the enigmatic Light Street fault near Bloomsburg and Briar Creek, and two anthracite strip mines near Hazleton (hopefully, including one that exposes the famous Mammoth coal bed). A special treat will be a visit to the Eckley Miners' Village.

If you are not on the current Field Conference mailing list and wish to attend the 1988 Conference, please write to Field Conference of Pennsylvania Geologists, c/o Pennsylvania Geological Survey, P. O. Box 2357, Harrisburg, PA 17120.

Urbanization Degrades Water Quality in Eastern Pennsylvania

The U.S. Geological Survey recently published a study assessing the impact of urbanization on groundwater and surface water. Although the study focuses on eastern Chester County, similar effects can be expected in other areas in Pennsylvania that are urbanized or undergoing development.

The results of the study are presented in the report **Effects of Urbanization on the Water Resources of Eastern Chester County, Pennsylvania,** by Ronald A. Sloto. The report, prepared in cooperation with the Chester County Water Resources Authority, was published as U.S. Geological Survey Water-Resources Investigations 87–4098.

It is demonstrated in the study that the most serious consequence of urbanization is degradation of groundwater quality. Volatile organic compounds were found in 39 percent of 70 wells sampled. The most serious effect on the surface-water system is the absorption and accumulation of PCB and pesticides on stream-bottom sediments. The author also pointed out substantial infiltration of groundwater to sewer systems, which reduces the base flow of streams.

Groundwater infiltration to one sewer system was as much as 4.9 million gallons per day and made up a greater percentage of the flow than did wastewater.

A limited number of copies of the report were printed. They are available from the U.S. Geological Survey, 4th Floor, Federal Building, P. O. Box 1107, Harrisburg, PA 17108-1107.

NEW STAFF MEMBER

David W. Valentino

David Valentino joined the Geologic Mapping Division of the Survey in late April 1988. He has been assigned to the Piedmont province mapping program, a new Survey effort to develop a modern understanding of the geology in southeastern Pennsylvania. David's initial task is to collect samples, measure geologic structures, and describe the rocks, all part of the preliminary approach to unraveling the geology of this metamorphic terrane that extends from York County to southern Bucks County.

David has a strong educational background ideally suited for working with the rocks of southeastern Pennsylvania, which are primarily metamorphic. He studied geology at Temple University, in Philadelphia, earning his Bachelor's degree in 1986 and a Master's degree this year, 1988. For the past year, David was a teaching and research assistant in the Geology Department at Temple; his duties included conducting laboratories in physical and structural geology, evolution, and catastrophic geology.

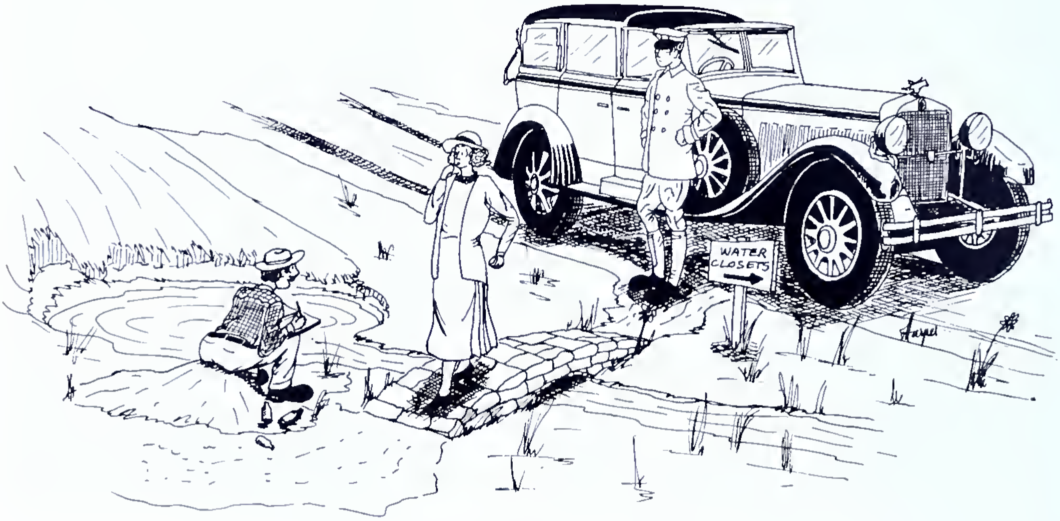
David's Master's thesis consisted of the mapping and interpretation of ductile shear zones along the Rosemont fault in Delaware County. During part of this research he was a volunteer for, and received support from, the Pennsylvania Geological Survey. David's wife Karen, who is graduating from Temple University in geology, also has a strong interest in metamorphic geology.

Photograph by M. L. Crawford

Geochips

During the summer and fall of 1933, Stan Lohman, a geologist of the U.S. Geological Survey, was studying the groundwater of south-central Pennsylvania in cooperation with the Pennsylvania Geological Survey. On October 13 he collected a sample of water from "Magnesia Spring," one of four springs of the Bedford Springs Hotel and Baths, situated a few miles south of the Borough of Bedford, the county seat of Bedford County. Water from "Magnesia Spring," which had a bitter taste, was used only for so-called medicinal baths. While Stan was filling out a tag to attach to the sample bottle, a long black limousine drove up and parked. The liveried chauffeur stepped out and opened the rear door, from which emerged a well-dressed woman. As she walked toward the spring for a drink, she took from her purse a folding aluminum drinking cup. When she saw the painted sign and saw Stan filling out the tag, she hesitated, and asked about the spring and what he was doing. After he explained the nature of his work, he mentioned that the water from this spring (which flowed about 30 gallons per minute from the Helderberg Limestone) had a bitter taste, and probably contained considerable magnesium sulfate, commonly called epsom salts. She exclaimed in alarm, "Epsom salts! Then—it will physic one, won't it?" He replied, "It shore will!" Whereupon, she thanked him for the warning, returned the cup to her purse, went back to the limousine, and was driven away.

Subsequent analysis of the water sample indicated that it contained considerable calcium and magnesium sulfate, and was the hardest and most highly concentrated sample of groundwater collected in the 14 counties covered by this investigation (see spring 992, p. 126, 132, and 139, in Pennsylvania Geological Survey Water Resource Report 5, 1938).



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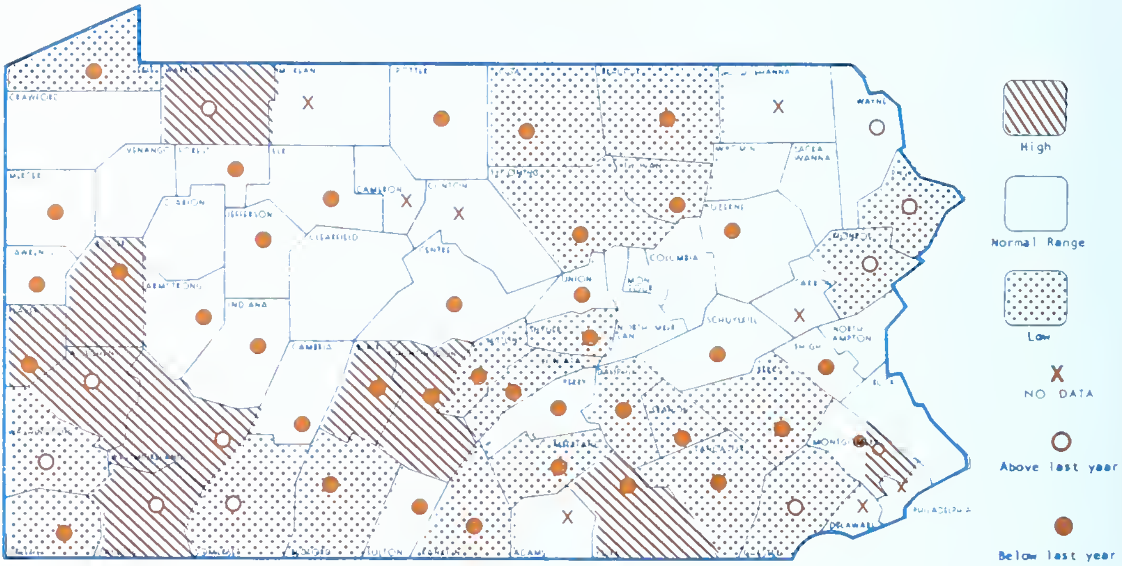

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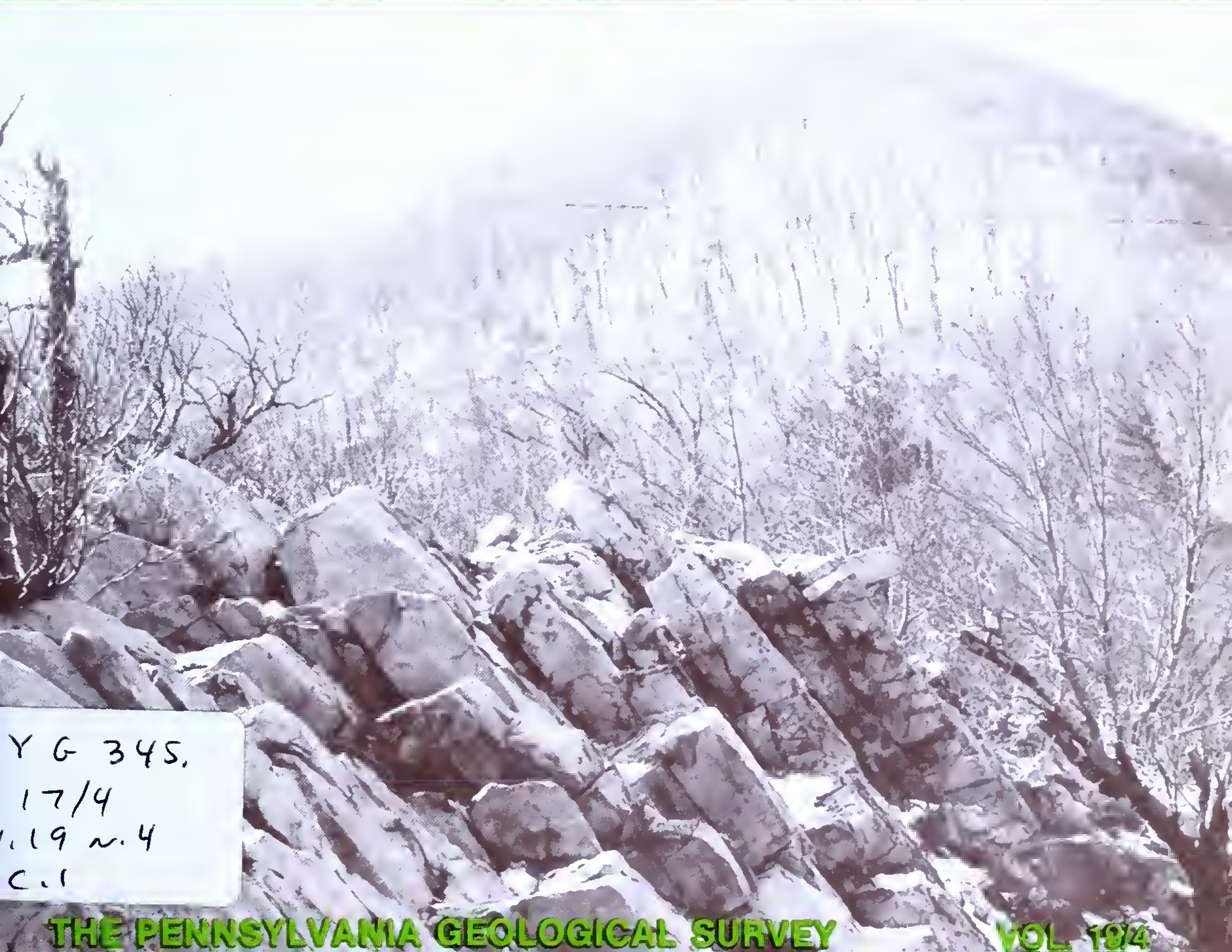

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THE PENNSYLVANIA GEOLOGICAL SURVEY

VOL. 19/4

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ON THE COVER: Quartzite beds in the Tuscarora Formation exposed along the crest of Brush Mountain. The view is toward the south, just north of the road over the mountain at Skelp Gap, about 3 miles northeast of Bellwood, Blair County. Photograph by R. T. Faill.

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VOL. 19, NO. 4 **AUGUST 1988**

SEP 28 1988

Science Versus Pseudoscience

Early in the spring of 1988 we were exposed to various media treatments of a circumstance of pseudoscience. There were television, radio, and newspaper accounts about the conclusions credulously reached by the Orson Welles film *The Man Who Saw Tomorrow,* a portrayal of the poetic prognostications of Nostradamus, a 16th-century astrologer. Over 2,000 Californians ordered the videotape of the film to see for themselves the conclusion that an earthquake would strike "New City," supposedly a California city, in April. Geophysicists and geologists are confident that earthquakes *will* occur in California, but all of the best science they perform will not allow prediction of exact dates. Only seers, astrologers, and other paranormals are willing to predict such events.

While California may have its share of residents willing to set aside rational acceptance of the limitations and ambiguities of geology, we, too, in Pennsylvania have our believers in the occult—in the secret of water smelling. A substantial portion of our population will accept the induced bending of hand-held twigs as indicating the location of waters hidden beneath the twig-holder's feet. No connection is made with the pervasive rain that they see fall on the earth's surface and the porous nature of the soil into which it percolates. Rather there is a preferred belief that hidden streams are rushing beneath our feet.

If we geologists are to reduce the popular acceptance of pseudoscience we must assist people in learning to understand the connection between natural events, such as the falling of rain with its disappearance into the soil, and its reappearance as water in a spring or well. Pseudoscience and the occult will flourish unless we translate the complexities of geology into understandable knowledge for all, not for just a few.

Donald M. Hoskins

State Geologist

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GEOLOGICAL RESEARCH IN PENNSYLVANIA

1988

Introduction

This publication, the thirty-first annual report in its series, contains a listing of all known current geological research in Pennsylvania and all known reports published during the past year pertaining to Pennsylvania geology. Because of the large number of projects reported to us, we editorially condense the descriptions to fit available space.

We have requested each person to estimate an anticipated completion date (ACD) for each project. The anticipated completion date is the author's estimate of the date when the project will be finished; additional time should be allowed for publication of the report.

If you wish more information on a project described herein, please write directly to the author; most of these projects will not be published by the Pennsylvania Geological Survey inasmuch as most are not Survey-sponsored projects.

The listings are grouped into major categories of research to facilitate your search for information on a particular subject. As with all compilations, there may be omissions; this is unintentional.

Additional copies of this report may be obtained by writing to the Bureau of Topographic and Geologic Survey, Department of Environmental Resources, P. O. Box 2357, Harrisburg, PA 17120.

Areal Geology

T. M. BERG and C. M. DODGE, Pa. Geol. Survey. **Map 61, Atlas of Preliminary Geologic Quadrangle Maps of Pennsylvania** (2nd ed.). The very popular "Map 61 Atlas" is being revised to include all quadrangles of Pennsylvania, and many corrections, additions, and changes are being included. This will provide users with a single, desktop source for all of the bedrock geology of the Commonwealth. ACD: 1990 or 1991.

T. M. BERG, Pa. Geol. Survey, and M. L. O'NEAL, C. B. CUBBISON, JACQUELINE LUNDY, and J. B. LESSMAN (all student interns, Pa. Geol. Survey). **Geologic Map of Warren County, Pennsylvania.** This map is being prepared for the Warren County groundwater report being compiled by M. E. Moore (Pa. Geol. Survey) and T. F. Buckwalter (U.S. Geol. Survey, Water Resources Division). ACD: Summer 1988.

R. T. FAILL and D. W. VALENTINO, Pa. Geol. Survey. **Geological Investigations in the Pennsylvania Piedmont.** Reconnaissance of the Piedmont province continues, which will soon lead to projects addressing specific geologic, petrologic, structural, and sedimentologic problems, such as the nature of the Peach Bottom syncline and Cream Valley fault, terrane boundaries within the Wissahickon, relations among the Grenville massifs and cover rocks, and other such matters.

J. D. INNERS, Pa. Geol. Survey. **Geology and Mineral Resources of the Hazleton Quadrangle, Luzerne, Carbon, and Schuylkill Counties, Pennsylvania.**

D. B. MacLACHLAN, Pa. Geol. Survey. **Geology of the Freeburg Quadrangle, Snyder County, Pennsylvania.** ACD: 1988.

W. D. SEVON, Pa. Geol. Survey. **Surficial Geology of the Conestoga, Holtwood, Quarryville, and Wakefield Quadrangles, Lancaster and York Counties, Pennsylvania.** ACD: 1988.

Economic Geology

S. W. BERKHEISER, JR., and R. C. SMITH, II, Pa. Geol. Survey. **Additional Occurrences of Specialty-Use Silica in Pennsylvania.** The purpose of the investigation is to identify and characterize Cambrian-age clastic resources within the South Mountain area of Adams, Cumberland, and Franklin Counties. Additional data concerning the thickness and quality of selected quartz veins and a few other sandstones are also included. Results of the analyses will be open-filed when reproducible Fe and Al values are available. A core hole anticipated to penetrate about 850 feet of sandstone and quartzite will be drilled in the 1988–89 winter season. ACD: Mid-1989.

S. W. BERKHEISER, JR., and R. C. SMITH, II, Pa. Geol. Survey. **Mineral Fillers of the Piedmont Physiographic Province of Pennsylvania.** Reconnaissance investigations of potential mica, talc, silica, and carbonate mineral fillers in the Piedmont physiographic province of Pennsylvania. These studies are preliminary in nature and support anticipated new mapping programs in the region. ACD: Ongoing.

S. W. BERKHEISER, JR., and R. C. SMITH, II, Pa. Geol. Survey. **Reconnaissance Investigations and Analyses of High-Purity Carbonate Resources in Pennsylvania.** Preliminary reconnaissance investigations with the object of updating and identifying new high-purity carbonate resources for use in the acid-mitigation fields. The Valley and Ridge physiographic province contains numerous carbonate sequences of Cambrian through Devonian age. ACD: Ongoing.

W. A. BRAGONIER, Rochester and Pittsburgh Coal Co., and A. D. GLOVER and J. G. PHILLIPS, Pa. Geol. Survey. **Coal Resources of Armstrong County, Pennsylvania—Part 1, Coal Crop Lines, Mined-Out Areas, and Structure Contours.** Published and unpublished data will be used to prepare a series of maps including (1) separate crop-line maps for each principal coal seam showing areas of strip and deep mining, and (2) composite maps showing the crop lines of all principal coals, as well as structure contours and fold axes. ACD: 1989.

W. A. BRAGONIER, Rochester and Pittsburgh Coal Co., and A. D. GLOVER and J. G. PHILLIPS, Pa. Geol. Survey. **Coal Resources of Indiana County, Pennsylvania—Part 1, Coal Crop Lines, Mined-Out Areas, and Structure Contours.** Published and unpublished data will be used to prepare a series of maps including (1) separate crop-line maps for each principal coal seam showing areas of strip and deep mining, and (2) composite maps showing the crop lines of all principal coals, as well as structure contours and fold axes. ACD: 1988.

C. H. DODGE, Pa. Geol. Survey. **Coal Resources of Elk County, Pennsylvania—Part 1, Coal Crop Lines, Mined-Out Areas, and Structure Contours.** Detailed geologic mapping of the coal-bearing strata (Pottsville, Allegheny, and Glenshaw Formations) of Pennsylvanian age. Emphasis is on the major coal-bearing structural basins. A series of maps will be prepared including (1) separate crop-line maps for each principal coal seam showing areas of strip and deep mining, and (2) composite maps showing the crop lines of major and minor coals, as well as structure contours and fold axes. ACD: 1990.

A. D. GLOVER, Pa. Geol. Survey. **Coal Resources of Jefferson County, Pennsylvania—Part 1, Coal Crop Lines, Mined-Out Areas, and Structure Contours.** Published and unpublished data will be used to prepare a series of maps including (1) separate crop-line maps for each principal coal seam showing areas of strip and deep mining, and (2) composite maps showing the crop lines of all principal coals, as well as structure contours and fold axes. ACD: 1991.

S. A. HAYNES, Pa. Geol. Survey. **Compilation of Rock and Soil Uranium Analyses and Occurrences in Pennsylvania.** All known uranium occurrences in Pennsylvania are being compiled on a single topographic map base at a scale of 1:500,000. This map will include information on host rock type, approximate tonnage of mineralized rock, high-grade occurrences, and references for each occurrence. ACD: June 1988.

L. J. LENTZ, Pa. Geol. Survey. **Coal Resources of Greene County, Pennsylvania—Part 2, Overburden Thickness, Coal Quality, and Coal Reserve Estimates.** Computer compilation and manipulation of coal data for Greene County continues. Data base includes point and line data, stratigraphic data, and chemical data in files managed by the U.S. Geological Survey in Reston, Virginia. ACD: Ongoing.

L. J. LENTZ, Pa. Geol. Survey. **Coal Resources of Washington County, Pennsylvania—Part 2, Overburden Thickness, Coal Quality, and Coal Reserve Estimates.** Computer compilation and manipulation of coal data for Washington County continues. Data base includes point and line data, stratigraphic data, and chemical data in files managed by the U.S. Geological Survey in Reston, Virginia. ACD: Ongoing.

A. K. MARKOWSKI, Pa. Geol. Survey, JIM ULERY, U.S. Bureau of Mines, JOAN HAWK, Rochester and Pittsburgh Coal Co., and DAVE DANON, Consolidated Natural Gas Co. **Preliminary Feasibility Study of the Coal-Bed Methane Resource in Pennsylvania.** ACD: June 1989.

S. T. PEES, Samuel T. Pees and Assoc. **Mapping the Main Sandstone Bundle of the Grimsby-Cabot Head Formations for Horizontal Drilling Purposes in Northwest Pennsylvania.** Project involves techniques of mapping the objective section of the Lower Silurian Medina Group for targeting horizontal penetration. Structural, stratigraphic, and geometric factors are applied in developing this methodology. ACD: May 1989.

G. R. ROBINSON, Project Chief, U.S. Geol. Survey. **Metallogeny of the Early Mesozoic Basins of the Eastern United States.** Two core holes in a diabase sheet in the Gettysburg basin have been logged and sampled for petrographic and geochemical analysis, and are currently being studied. Field work and other geologic studies in the Newark basin of New Jersey and Pennsylvania, the narrow neck area between the Newark and Gettysburg basins of Pennsylvania, and the Culpeper basin of Virginia are continuing. We are in the process of bringing to completion many of the ongoing topical studies. We hope to complete preliminary versions of a suite of maps covering all of the exposed early Mesozoic basins of the eastern United States and expect to have many of these maps ready for review by Summer 1988.

C. B. SCLAR and P. H. BENOIT, Lehigh Univ. **Comparative Chemical Study of the "Vein" Chromite and the Massive Chromite from the Wood's Chrome Mine, State Line District of Pennsylvania-Maryland.** The chromite deposit at the Wood's chrome mine consists of massive chromite and "vein" chromite. The origin of the latter has been the source of much controversy. A comparative electron microprobe analysis of "vein" and massive chromite should yield chemical clues as to the origin of the "vein" chromite. ACD: June 1990.

V. W. SKEMA, Pa. Geol. Survey. **Coal Resources of Clearfield County, Pennsylvania—Part 1, Coal Crop Lines, Mined-Out Areas, and Structure Contours.** Detailed geologic mapping of the coal-bearing strata of Pennsylvanian age. Emphasis is on the major coal-bearing structural basins. A series of maps will be prepared including (1) separate crop-line maps for each principal coal seam showing areas of strip and deep mining, and (2) composite maps showing the crop lines of major and minor coals, as well as structure contours and fold axes.

R. C. SMITH, II, and S. W. BERKHEISER, JR., Pa. Geol. Survey. **Reconnaissance for Precious Metals in Southeastern Pennsylvania.** Plan to conduct a whole-rock and stream heavy-mineral reconnaissance of two test 7½-minute quadrangles. Representative rock composites will be analyzed for trace Ag-Au-Pb-Pt. Frantz separates of panned concentrates will be identified. ACD: Ongoing.

R. W. STANTON, Project Chief, U.S. Geol. Survey. **Petrology of North American Coals.** Goals include evaluating geologic effects on the geometry and controls on quality and petrographic composition of the Lower Freeport coal bed, west-central Pennsylvania. Focus of the work will be to evaluate what effect the adjacent sedimentary units contributed to the quality and extent of peat facies and how these differences affect washability characteristics of the resulting coal.

A. M. STERNAGLE, Pa. Dept. of Transportation. **History of the Blair and Huntingdon Counties Iron Industry.** History of early charcoal and coke-fueled iron furnaces with special emphasis on the rock units utilized. To date furnace sites have been located and ore banks are being studied in relation to mining practices. ACD: Ongoing.

TIM WHITE and ALAN DAVIS, Pa. State Univ. **An Evaluation of Sulfur Forms and Pyrite Morphology in the Upper and Lower Clarion Coals** [Piney Twp., Clarion Co.]. The need to reduce sulfur levels in cleaned coal requires a better understanding of the distribution of sulfur forms and pyrite morphology in the seams. This project characterizes these parameters in a high-volatile bituminous coal. ACD: Midsummer 1988.

TIM WHITE and ALAN DAVIS, Pa. State Univ. **Regional Topographic Controls on the Modes of Occurrence and Distribution of Sulfur in the Lower Kittanning Seam** [north-central and central Pa.]. A series of sampling traverses were made from paleotopographic low areas onto the Kane High. Sulfur forms, sulfur distribution, and modes of occurrence of pyrite will be determined to establish any regional trends. Local variations will be identified. ACD: Fall 1988.

Engineering Geology

D. D. BRAUN and NORMAN GILLMEISTER, Bloomsburg Univ., and J. D. INNERS, Pa. Geol. Survey. **Dip Slope Rock Block Slides in the Valley and Ridge of Northeastern Pennsylvania.** Rock block slides as large as 20,000,000 m^3 occur at four sites where dip slopes are undercut by rivers or by man. Slippage occurs within mudstone units, and the blocks are bounded by joints or the ground surface. Historic slides are associated with high-moisture conditions. Work continues at additional sites. ACD: Summer 1989.

W. B. FERGUSSON and E. F. GLYNN, Villanova Univ. **Engineering Characteristics of the Unconsolidated Rocks and Bedrock Beneath the City of Philadelphia.**

K. D. SVITANA, Benatec Assoc. **Design Considerations for Underground Storage Tank Installations Requiring Secondary Containment: A Case Study** [Middlesex Twp., Cumberland Co.]. Soil and bedrock characteristics were analyzed to determine the best method of secondary containment for an underground storage tank farm. The design goal was for total containment of petroleum product spillage and leakage. ACD: June 1987.

Environmental Geology

H. L. DELANO, Pa. Geol. Survey. **Preliminary Characterization of Lake Erie Bluff Sediments.** Reconnaissance mapping and sample analysis of selected areas of Pennsylvania's lake shore. Results will be used to design a work plan for a larger, comprehensive study of the environmental geology of the lake shore area. ACD: Summer 1988.

S. A. HAYNES, R. C. SMITH, II, L. T. CHUBB, and M. A. GLENN (summer assistant), Pa. Geol. Survey. **Assessment of Potential Radon-Prone Areas in the Triassic-Age Sedimentary Rocks of Bucks County, Pennsylvania.** Airborne gamma-ray data for Bucks County have been field investigated and interpreted. A carborne gamma-ray survey covering 40 percent of the county has been completed. Thirty-one previously undescribed uranium enrichments have been discovered, sampled, and analyzed for uranium and selected trace elements. ACD: June 1988.

W. E. KOCHANOV, Pa. Geol. Survey. **Karst, Sinkholes, and Engineering Considerations in the Carbonate Terrains of Pennsylvania.** ACD: Winter 1989.

W. E. KOCHANOV, Pa. Geol. Survey. **Sinkholes and Karst-Related Features of Cumberland County, Pennsylvania.** ACD: Fall 1988.

W. E. KOCHANOV, Pa. Geol. Survey. **Sinkholes and Karst-Related Features of Dauphin County, Pennsylvania.** ACD: Fall 1988.

W. E. KOCHANOV, Pa. Geol. Survey. **Sinkholes and Karst-Related Features of Franklin County, Pennsylvania.** ACD: Fall 1988.

A. W. ROSE, JOHN WASHINGTON, DANIEL GREEMAN, EDWARD CIOLKOSZ, and WILLIAM JESTER, Pa. State Univ. **Generation and Migration of Radon in Soils** [eastern U.S.]. The controls on radon in soil gases and the geochemistry of radium in soils are being investigated in about 12 soil profiles representing a range of soil types and conditions typical of the eastern United States. ACD: 1990.

J. P. WILSHUSEN and staff members, Pa. Geol. Survey. **Scenic Geological Features of Pennsylvania.** A revision of Pennsylvania Geological Survey Environmental Geology Report 7, *Outstanding Scenic Geological Features of Pennsylvania.* ACD: June 1990.

General Geology

T. M. BERG, Pa. Geol. Survey. **Pennsylvania Geology Summarized.** This revision of Bradford Willard's famous educational pamphlet (Pennsylvania Geological Survey Educational Series 4) will provide all age groups with a modern understanding of the geology of the Commonwealth, and will relate the geology as seen in visible geomorphic features to dynamic earth processes ranging from erosion and deposition to the movement of continental plates. ACD: Late 1988.

T. M. BERG, Pa. Geol. Survey, THOMAS BALDWIN, Pa. Dept. of Environ. Resources, Bur. of Inf. Resources Mgt., and ROBERT AGNEW, Pa. Dept. of Environ. Resources, Bur. of Mining and Reclamation. **Geographic Information Systems in the Department of Environmental Resources.** This three-man committee has assessed all of the potential areas within the Department of Environmental Resources (DER) where a Geographic Information System (GIS) would have application and impact on map production. When a GIS is established in DER, the Pennsylvania Geological Survey will have greatly enhanced capabilities in the production of bituminous-coal maps and aquifer-characteristics maps. ACD: Ongoing.

H. L. DELANO, Pa. Geol. Survey. **Presque Isle State Park.** This layman's park guide will include a discussion of the origin and history of the peninsula, coastal erosion and depositional processes and features, and engineering efforts to limit erosion. ACD: Summer 1988.

J. A. HARPER, Pa. Geol. Survey. **Geology of the Pittsburgh Area.** The popular *Geology of the Pittsburgh Area* (Pennsylvania Geological Survey General Geology Report 59) will be revised and updated to provide new information and new localities. ACD: 1988.

J. A. HARPER, Pa. Geol. Survey. **Oil Creek State Park.** ACD: 1988.

D. M. HOSKINS, Pa. Geol. Survey. **William Darby, Pennsylvania Geographer and Map Maker of the 1820's.** Although not a geologist, William Darby traveled throughout Pennsylvania and the states of the Ohio and Mississippi making geological observations. Using the

1817 Maclure map of the eastern United States, Darby prepared the first geologic map of a state and included on it the newly mapped contact between the Martinsburg and subjacent limestones, the first mapping of a modern formation contact. ACD: 1989.

JOHN REPETSKI and J. T. DUTRO, JR., U.S. Geol. Survey, A. R. PALMER, Geol. Soc. of America, G. R. GANIS, Tethys Consultants, Inc., and D. A. HOPKINS, J. E. Baker Co. **New Cambrian Fossil Localities and a Revised Geology of the York Valley.** New Cambrian fossil localities in the West York quadrangle indicate that all of the formations in that area are of Early or Middle Cambrian age. The indicated time-transgressive nature of the rock units in the Conestoga Valley between York and Lancaster Counties supports the model proposed by John Rodgers in 1968. The "Conestoga" Formation of the York area appears to be the time equivalent of the upper Kinzers Formation in Lancaster County. An unconformity below the "Conestoga" is not indicated in the York area. ACD: 1989.

C. H. SHULTZ, ed., Slippery Rock Univ. and Pittsburgh Geol. Soc. **The Geology of Pennsylvania.** This book-writing project is being developed and managed by the Pittsburgh Geological Society. The book will be published by the Pennsylvania Geological Survey; it will be of large format and about 600 pages long with 16 pages of color. Writers are about equally divided among government, industry, and academia. Most writing units have undergone editorial review and have been revised or revisions are pending.

Geochemistry

MICHAEL BIKERMAN, RALPH FEATHER, and C. D. McNAUGHTON, Univ. of Pittsburgh. **Uplift Chronology of the Pennsylvania Appalachians by K-Ar and Fission-Track Methods.** Sample collecting and laboratory preparation are underway. ACD: 1990.

K. R. CERCONE and J. F. TAYLOR, Indiana Univ. of Pa. **Preservation of Metastable Skeletal Carbonates in the Missourian Brush Creek Marine Interval, Indiana and Armstrong Counties.** Thin section and SEM studies of the Brush Creek marine interval have shown that both metastable aragonite and calcite are preserved as skeletal fragments in shale. Total organic carbon contents of these shales range from 0.8 to 2.0 percent. Preservation of metastable carbonates appears to correlate with increased amounts of amorphous-sapropelic organic matter. ACD: Ongoing.

R. K. KOTRA, Project Chief, U.S. Geol. Survey. **Organic Geochemistry.** Work is currently in progress on a number of black shale samples from Bucks County (Lockatong Formation, Newark basin). The samples provided by the Pennsylvania Geological Survey are being analyzed for organic carbon content and other parameters to determine their source rock quality. Results of the analyses will be evaluated during the latter part of FY 1988 and in FY 1989. This data set will contribute to the overall understanding of the quality and distribution of organic-rich strata in the early Mesozoic basins of the eastern United States.

C. D. LAUGHREY, Pa. Geol. Survey. **Geochemistry of Petroleum Source Rocks in Pennsylvania.** ACD: 1989.

J. M. McNEAL, Project Chief, U.S. Geol. Survey. **Geochemical Exploration Techniques for the Eastern Triassic Basins.** The NURE data and geochemical maps for the Newark basin will be completed hopefully in Winter 1988–89 and for the Gettysburg basin in Spring 1989. Reports on groundwater chemistry for portions of the Newark basin and the Gettysburg basin (Zora Ring complex) are expected to be completed by October 1989.

M. K. RODEN and D. S. MILLER, Rensselaer Polytechnic Inst. **Thermal History of the Central and Southern Appalachian Basin (Pennsylvania, Maryland, Virginia, and West Virginia) Based on Apatite Fission-Track Thermochronology.** Thirty-two samples of Tioga Ash Bed and Upper Devonian sediments were collected from the Appalachian basin in Pennsylvania for apatite fission-track analysis. Preliminary results indicate apatite fission-track apparent ages younger than depositional age (390 Ma). This shows that the sediments were subjected to temperatures greater than 100°C prior to approximately 250 Ma ago. ACD: Sept. 1988.

Geomorphology

T. M. BERG, J. H. BARNES, W. D. SEVON, V. W. SKEMA, and J. P. WILSHUSEN, Pa. Geol. Survey. **Physiographic Provinces of Pennsylvania.** In this project, the page-sized *Physiographic Provinces of*

Pennsylvania (Pennsylvania Geological Survey Map 13) is being revised to more accurately delineate the geomorphic regions of the state. ACD: Summer 1988.

T. W. GARDNER, JOHN RITTER, JAY BELL, KATHY CONNORS, CHRIS SHUMAN, and NICK PINTER, Pa. State Univ. **Deposition Environments of Grezes Litees in Pennsylvania.** Geographic distribution, hillslope properties, and depositional environments of grezes litees (shale-chip rubble) are being described for these deposits in central Pennsylvania. ACD: Fall 1988.

M. D. GUEBERT and T. W. GARDNER, Pa. State Univ. **Relationship of Remotely Sensed SPOT Data to Infiltration Capacity of Surface-Mined Land in Central Pennsylvania** [northwestern Centre Co.]. Comparison of infiltration capacity and SPOT data for mined-land surface features indicates that SPOT imagery provides a spatially extensive and detailed characterization of infiltration properties on spatially complex surface-mined land. ACD: May 1988.

J. V. HAMEL, Hamel Geotechnical Consultants, and R. B. JACOBSON, U.S. Geol. Survey. **Archeo-Geological Investigation of a Monongahela River Terrace South of Masontown.** Geological and pedological investigations showed that a large terrace along the Monongahela River south of Masontown formed by slackwater deposition when the river was temporarily ponded by a dam of glacial outwash near Pittsburgh circa 80,000 to 60,000 years B.P. ACD: Sept. 1988.

J. B. RENK, III, and R. A. VARGO, Calif. Univ. of Pa. **Structural Control in the South Fork Drainage Basin, Greene County, Pennsylvania.** ACD: Dec. 1988.

J. B. RITTER and T. W. GARDNER, Pa. State Univ. **Temporal Variation in Water and Sediment Discharge from Disturbed Watersheds, Central Pennsylvania** [Centre and Clearfield Cos.]. The variation in water and sediment yield from disturbed basins is examined as a function of time since reclamation. Surface-water models and preliminary field observations suggest variation due to time-dependent changes in infiltration properties and drainage network expansion. ACD: 1990.

T. W. SMALL, Frostburg State Univ., and RANDY SCHAETZL, Michigan State Univ. **Spatial Redistribution of Gravels Within Soils by Tree Uprooting** [Potter Co.]. Stone and gravel concentrations are being examined within and adjacent to treethrow mound sites. Stone concentrations "armor" the mound to surficial erosion processes and in the long run are left as surficial lag deposits. ACD: Spring 1989.

Geophysics

K. P. KODAMA and JOHN STAMATAKOS, Lehigh Univ., and ART GOLDSTEIN, Colgate Univ. **Effects of Simple Shear Strain on Remanence** [Middle Paleozoic units, central Pa.]. We will be studying the effects of simple shear strain during folding on magnetic remanence. ACD: 1990.

J. D. PHILLIPS, Project Chief, U.S. Geol. Survey. **Geophysical Mapping of Early Mesozoic Basins.** Work performed included magnetic-susceptibility logging of diabase core from the York Haven diabase sheet at Reesers Summit, New Cumberland, Pennsylvania. The magnetic-susceptibility log was used to correlate stratigraphic positions in the core hole with surface outcrops. Compilation of gridded digital aeromagnetic data for the Gettysburg and Newark basins and vicinity was completed, and photographic images of the data were prepared.

Glacial Geology

D. D. BRAUN, Bloomsburg Univ. **Glacial Geology of the Anthracite Region Outside of the Late Wisconsinan Border** [Middle and Southern Anthracite basins]. Pre-Wisconsinan glacial deposits are buried by as much as 20 m of colluvium and are only exposed in strip mines. The maximum extent of glaciation crosses the Southern basin at Tuscarora and wraps around the east end of the Western Middle basin at Delano. As much as 50 m of glacial sediment is present within or next to the Eastern Middle basin. ACD: First stage, Fall 1988.

D. D. BRAUN, Bloomsburg Univ. **Testing the Use of Secular Changes in Geomagnetic Declination for Correlation of Ice Margins Across the Appalachian Plateau** [north-central Pa.]. An insufficient number of undeformed glacial-lake sediment sites have been found to develop a usable geomagnetic declination record. Nearly all streams in the region have been walked out, and that field data will be used to develop a glacial-lake and ice-margin sequence across the area. ACD: 1989–90.

W. D. SEVON, Pa. Geol. Survey. **Surficial Deposits of the Wellsboro and Towanda 30- by 60-Minute Quadrangles, Pennsylvania and New York.** The surficial geology, mainly glacial deposits, colluvium, and alluvium, of sixty-four 7½-minute quadrangles has been mapped and compiled at 1:100,000 scale. ACD: May 1988.

D. W. WATSON, Slippery Rock Univ. **Glacial Evolution of the Slippery Rock Creek Gorge, McConnells Mill State Park, Pennsylvania.** ACD: June 1988.

Hydrology

T. F. BUCKWALTER, U.S. Geol. Survey, and M. E. MOORE, Pa. Geol. Survey. **Groundwater Resources of Warren County, Pennsylvania.** Countywide groundwater conditions will be evaluated. Extensive water-quality data will be used to determine impacts of oil and gas production on the resource. A revised geologic map will be included. ACD: Dec. 1988.

S. J. LANG, Erie County Health Dept./Environ. Services, and D. B. RICHARDS, Acting Project Chief, U.S. Geol. Survey. **Groundwater of Erie County, Pennsylvania.** The objective is to compile data on the quality and quantity of the groundwater in Erie County. Activities include well drilling, aquifer tests, seismic studies, and water sampling (general, pollution sites, and pesticide survey). ACD: 1990.

RICHARD LOWRIGHT and PATRICIA SCHNEIDER, Susquehanna Univ. **Concentrations of Selected Ions in Groundwater from the Tonoloway and Keyser Formations in Snyder County, Pennsylvania.** Published data on water chemistry from these rock units in the region are few. Preliminary analysis of the data indicates three possible sources for the contaminants. Further work should help to begin to discriminate the sources. ACD: Dec. 1988.

D. R. WILLIAMS, U.S. Geol. Survey, and T. A. McELROY, Pa. Geol. Survey. **Geology and Water Resources of Indiana County, Pennsylvania.** Approximately 500 wells and 100 springs have been inventoried throughout the county, many of which were sampled for water-quality characteristics. The 31 surface-water sites were sampled three times for low and high base flow water-quality characteristics. ACD: Sept. 1989.

D. S. YANNACCI, Pa. Geol. Survey, and DENNIS LOW and DANIEL HIPPE, U.S. Geol. Survey. **Aquifer Characteristics of the Rocks of**

Pennsylvania. A comprehensive summary of the hydrogeologic characteristics of Pennsylvania will be developed. The study will include an investigation of hydrogeologic characteristics of individual formations as well as regional flow systems. ACD: June 1989.

Igneous and Metamorphic Petrology

T. H. BRICE, Bryn Mawr Coll. **Relationship Between the Springfield Granodiorite and the Wissahickon Schist** [predominantly in the Lansdowne quad., extending into adjacent quads.]. ACD: May 1989.

JOSEPH HULL, Univ. of Rochester, and JOHN PUFFER and BOB KOTO, Rutgers Univ. **Ordovician "Group 4" Alkalic Magmatism in the North-Central Appalachians** [Pa., N. J., and N. Y.]. The age relationships, petrology, and geochemistry of Ordovician alkalic diabase dikes from Pennsylvania, New Jersey, and New York have been described. These dikes and related plutons form a syntectonic to late tectonic, collision-related alkalic suite ("Group 4").

Paleontology

CAROL FAUL and CHI KIM, Univ. of Pa. **A Study of the Eurypterids of the Shawangunk Formation (Silurian) of Pennsylvania and New Jersey.** ACD: Sept. 1988.

A. G. HARRIS, Project Chief, U.S. Geol. Survey. **Lower Paleozoic Conodont Studies, Appalachian Basin.** Ongoing investigations of Middle and Upper Ordovician rocks involve occasional field work in Pennsylvania to refine the conodont biostratigraphy of sections previously sampled or to add new paleontologic information to the existing data base.

R. LITWIN, Project Chief, U.S. Geol. Survey. **Mesozoic Palynology of the Atlantic Continental Margin.** This study is underway to examine the possibility that the Jacksonwald syncline in the Newark basin (Berks County) contains a nearly continuous sedimentary sequence through the Triassic-Jurassic boundary interval. To date, 10 palyniferous stratigraphic levels in the first 20 m immediately below the Jacksonwald Basalt, plus one above the basalt, have been identified. The fossil assemblages examined so far do not conclusively confirm the boundary, and additional samples are being sought from both lower and higher in the section. Auxiliary work has also begun in the Gettysburg basin to identify and collect palyniferous horizons in order to compare its palynological sequences with those of the Culpeper basin immediately to the south.

W. A. OLIVER, JR., U.S. Geol. Survey. **Corals and Biostratigraphy of the Keyser and Helderberg Limestones in the Appalachian Basin** [N. Y., N. J., Pa., Md., W. Va., and Va.]. Rugose corals are being described, and their stratigraphic and areal distribution analyzed, from the fine-grained, stromatoporoidal facies of Pridolian-Lochkovian age. ACD: Ongoing.

C. WNUK, Project Chief, U.S. Geol. Survey. **Paleoecology of Coal and Coal-Bearing Rocks.** The objective is the development of an improved understanding of the environmental, edaphic, ecological, and climatological factors that influence the development of peat-forming plant communities, and, consequently, affect coal quality, thickness, and distribution. The investigations are concentrating on the *in situ* floras found in the underclays beneath coal beds. Intensive study of a fossil assemblage that occurs in the underclay of the Mammoth #8 coal bed in the Shamokin quadrangle has led to the reconstruction of the growth form and ontogeny of the lycopod *Bothrodendron punctatum*. Additional studies and field work are expected to continue throughout the year.

PAUL ZELL. **Paleontology of the Lower Ordovician Nittany Dolomite in Central Pennsylvania.** ACD: Ongoing.

Sedimentology

EDWARD COTTER and JOHN LINK, Bucknell Univ. **Clinton Ironstones in Their Sedimentologic Context** [central Pa.]. ACD: 1990.

J. A. DIEMER, Univ. of N. C. at Charlotte. **Sedimentology and Paleohydraulic Reconstructions of the Catskill Formation, South-Central Pennsylvania.** The sedimentology of the Sherman Creek, Clarks Ferry, and Duncannon Members of the Catskill Formation have been described in detail. The depositional environments have been interpreted qualitatively. Paleohydraulic reconstructions are underway using point-bar deposits. ACD: Dec. 1989.

RICHARD GROLL and R. A. VARGO, Calif. Univ. of Pa. **Crossbedded Sandstone Formations of the Pittsburgh Group in Southwestern Pennsylvania** [California quad. and adjacent quads.]. ACD: May 1988.

T. M. MURIN, Univ. of Pittsburgh. **Sedimentology and Structure of the First Bradford Sandstone in the Pennsylvania Plateau Province** [southwestern Pa.]. ACD: Aug. 1988.

RUDY SLINGERLAND, DAVID SMETLAND, MARK ERIKSEN, and DIDIER MARSON, Pa. State Univ. **Circulation and Sediment Transport Modelling in the Late Devonian Catskill Epeiric Sea** [central and western Pa.]. A three-dimensional hydrodynamic computer model of the Late Devonian Catskill Sea has been constructed to better understand the fluid and sediment circulation processes along the Catskill coast. Early results suggest net wind- and tide-driven flows were to the southwest, consistent with outcrop paleocurrent data. Additional simulations with density stratification are planned for the next year. ACD: 1990.

S. D. WEEDMAN and A. L. GUBER, Pa. State Univ. **Depositional Environment of the Upper Freeport Limestone** [Armstrong and Indiana Cos.]. ACD: Summer 1988.

D. L. WOODROW, Hobart and William Smith Colls. **Shoreline Facies and Processes in the Catskill Delta, New York and Pennsylvania** [Tioga, Pike, and Warren Cos.]. ACD: June 1989.

Stratigraphy

J. R. EGGLESTON, Project Chief, U.S. Geol. Survey. **Framework of the Pennsylvania Anthracite Region.** Project efforts are concentrated on the Northern Anthracite field, where stratigraphy and structure are being developed. The project also includes paleobotanical studies, characterization of the Mill Creek Limestone, and depositional interpretations.

A. D. GLOVER, C. H. DODGE, L. J. LENTZ, J. G. PHILLIPS, J. R. SHAULIS, and V. W. SKEMA, Pa. Geol. Survey. **TASIC (Temporarily Available Stratigraphic Information Collection).** A continuing program to collect stratigraphic data and coal samples for analysis in active coal and clay mines in north-central and western Pennsylvania. The project will provide data for future mapping and regional resource evaluation. ACD: Ongoing.

W. M. GOODMAN and C. E. BRETT, Univ. of Rochester. **Stratigraphic Dynamics of the Silurian Northern Appalachian Basin** [Ont., N. Y., and Pa.]. We are conducting a small-scale stratigraphic analysis of the Wenlockian Series of the northern Appalachian basin, utilizing models of cyclic and event stratification to establish correlations between the New York and Pennsylvania outcrop belts. ACD: May 1988.

P. C. LYONS, Project Chief, U.S. Geol. Survey. **Physical Stratigraphy of the North-Central Appalachian Basin.** Regional coalification and diagenesis in the Pennsylvanian of the northern Appalachian basin is being studied using vitrinite reflectance, H:C and O:C atomic ratio data, illite crystallinity, conodont coloration, and argon geochemistry of feldspar from carboniferous sandstone. This study will relate coalification and diagenesis to structure, deposition, and tectonics. Work will be extended in 1988 and 1989 into the Broad Top and Northern Anthracite fields of Pennsylvania.

G. R. McGHEE, Rutgers Univ., and A. G. WARNE, Univ. of N. C. at Chapel Hill. **Stratigraphic Subdivisions of the Upper Devonian Scherr-Foreknobs and Lock Haven Formations near the Allegheny Front of Central Pennsylvania, U.S.A.** ACD: Mid-summer 1988.

R. C. SMITH, II, and S. W. BERKHEISER, JR., Pa. Geol. Survey, and J. H. WAY, Lock Haven Univ. **Lower Devonian and Other Bentonites and Ash Beds** [Valley and Ridge of central Appalachians]. Three distinctive bentonite beds have been correlated from Cherry Valley, New York, to New Creek, West Virginia. At nine Pennsylvania localities, they have been observed at or very near the traditional New Scotland-Mandata contact. ACD: Ongoing.

Structural Geology

A. E. GATES, Rutgers Univ. at Newark. **Sheer Sense Indicators in the Kirkwood-Rising Sun, Pennsylvania-Maryland, State Line Area.** Project involves mapping of shear zones in the State Line ultramafic body and relating them to the multiple deformations in the Peters Creek Schist to the north. Field work is essentially complete; structural analysis is in progress. ACD: June 30, 1988.

M. B. GRAY, Univ. of Rochester. **Structural Evolution of the Central and Southern Anthracite Region.** I plan to identify and better constrain the geometry and topology of the regional detachments, and determine the relative timing of folding, metamorphism, and the movement on major thrust faults. ACD: 1990.

M. L. HILL and GEORGE MEYER, Temple Univ., and D. W. VALENTINO, Pa. Geol. Survey. **Structure of the Martic Zone, Pennsylvania Piedmont** [Quarryville, Pa., to Trenton, N. J.]. The Martic Zone, a major ductile shear zone with dextral transcurrent displacement, strikes N70°E across the Piedmont. A goal of this investigation is to assess the magnitude and timing of displacement. ACD: 1990.

R. P. NICKELSEN, Bucknell Univ. **Structural Evolution of Northwest Limbs of First-Order Anticlines in the Valley and Ridge Province—Area 1, McConnellsburg area** [McConnellsburg, Meadow Grounds, Burnt Cabins, and Big Cove Tannery quads.]; **Area 2, Williamsburg area** [Williamsburg, Frankstown, and Spruce Creek quads.]. Northwest limbs of first-order anticlines west of both McConnellsburg and Williamsburg show imbricate faults, perhaps formed as duplexes in horizontal strata prior to being folded to their present attitude. I am doing this research to see if the evolutionary model already used to interpret such structures on the northwest limb of the Kishacoquillas Valley anticline can also be applied in these two other areas. ACD: Jan. 1988.

S. T. PEES, Samuel T. Pees and Assoc. **The Structural Configuration of the Upper Ordovician Queenston Formation Surface in Northeastern Ohio, Northwestern Pennsylvania, Southwestern New York, and the Lake Erie Portion of the Province of Ontario.** Detailed regional contours of the disconformable (locally unconformable) Queenston Formation surface will be presented with a description of the lithology of beds immediately above and below the contact. Structural deformation patterns are shown and discussed. ACD: Sept. 1988.

L. B. PLATT, Bryn Mawr Coll., and D. H. HARRISON, Arizona State Univ. **Compressive Strain in a Fold in Mesozoic Rocks near Reading, Pennsylvania.** Pencil cleavage and deformed mud cracks far from the border fault show compessive strain of about 10 percent.

L. B. PLATT and STACEY TYBURSKI, Bryn Mawr Coll. **Reconnaissance of Strain in Fossils in the Valley and Ridge Province.** ACD: May 1988.

S. I. ROOT, Coll. of Wooster. **Structure and Hydrocarbon Potential of the Gettysburg Basin, Pennsylvania and Maryland.** ACD: Completed.

D. W. WATSON, Slippery Rock Univ. **Structural and Joint Study of Slippery Rock Creek Gorge Area, McConnells Mill State Park, Pennsylvania.** ACD: Ongoing.

REPORTS PUBLISHED

Areal Geology

Birnie, R. W., and **DeFeo, Nancy,** 1987, Lithologic mapping using geobotanical and Landsat thematic mapper data [abs.]. AAPG Bulletin, v. 71, no. 5, p. 531.

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A Change on the Map of Groundwater Levels

by Michael E. Moore
Pennsylvania Geological Survey

Most readers of *Pennsylvania Geology* have been introduced to the state's observation-well network via the map of monthly groundwater levels that has appeared on the back cover since the first issue in 1969. Pennsylvania has a long history of groundwater monitoring, having first employed a network of observation wells in 1931. Today the network is operated cooperatively by the U.S. Geological Survey and by two bureaus within the Pennsylvania Department of Environmental Resources—Water Resources Management and Topographic and Geologic Survey. Although the size and mission of the network have changed in its 57 years of existence, these modifications have been minor compared to the changes in data-collection methods. Periodic measurements using steel tape and chalk eventually gave way to the continuous records from graphic recorders and digital punch tapes. Today 19 of 57 wells have had the

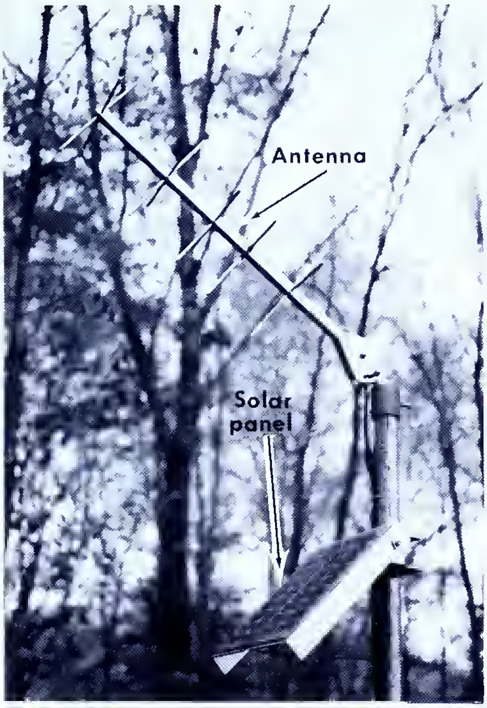
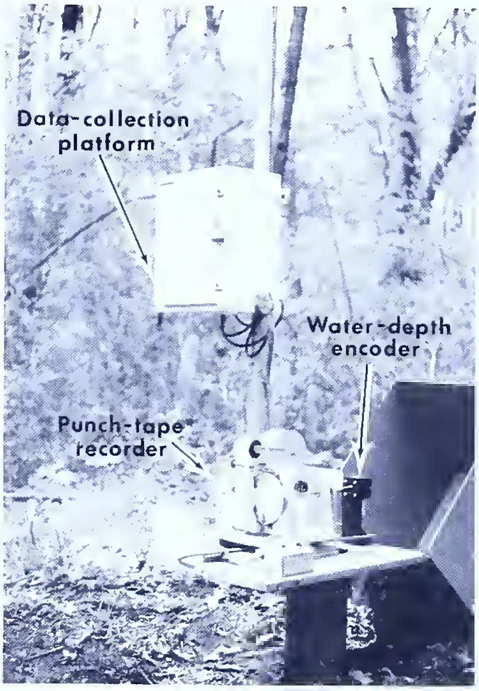


Figure 1. Equipment for monitoring water levels at network well Da-350, Dauphin County.

continuous recorders either replaced or supplemented with electronic data-collection platforms (DCP's) (Figure 1). Each DCP transmits digital water-level data every 4 hours, via satellite, to the Water Resources Division of the U.S. Geological Survey. Starting with this issue, observation wells equipped with data-collection platforms are identified on the map.



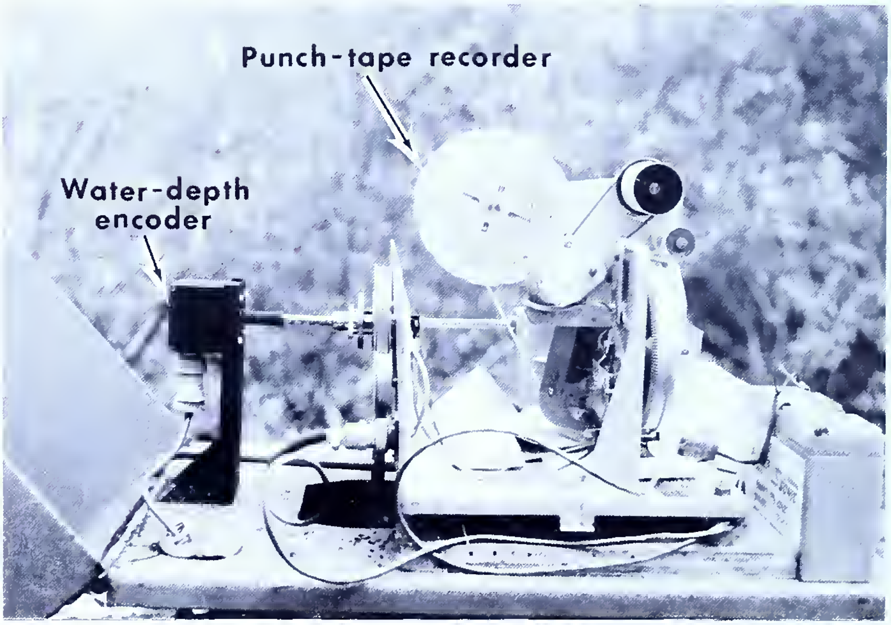


Figure 1. *(Continued).*

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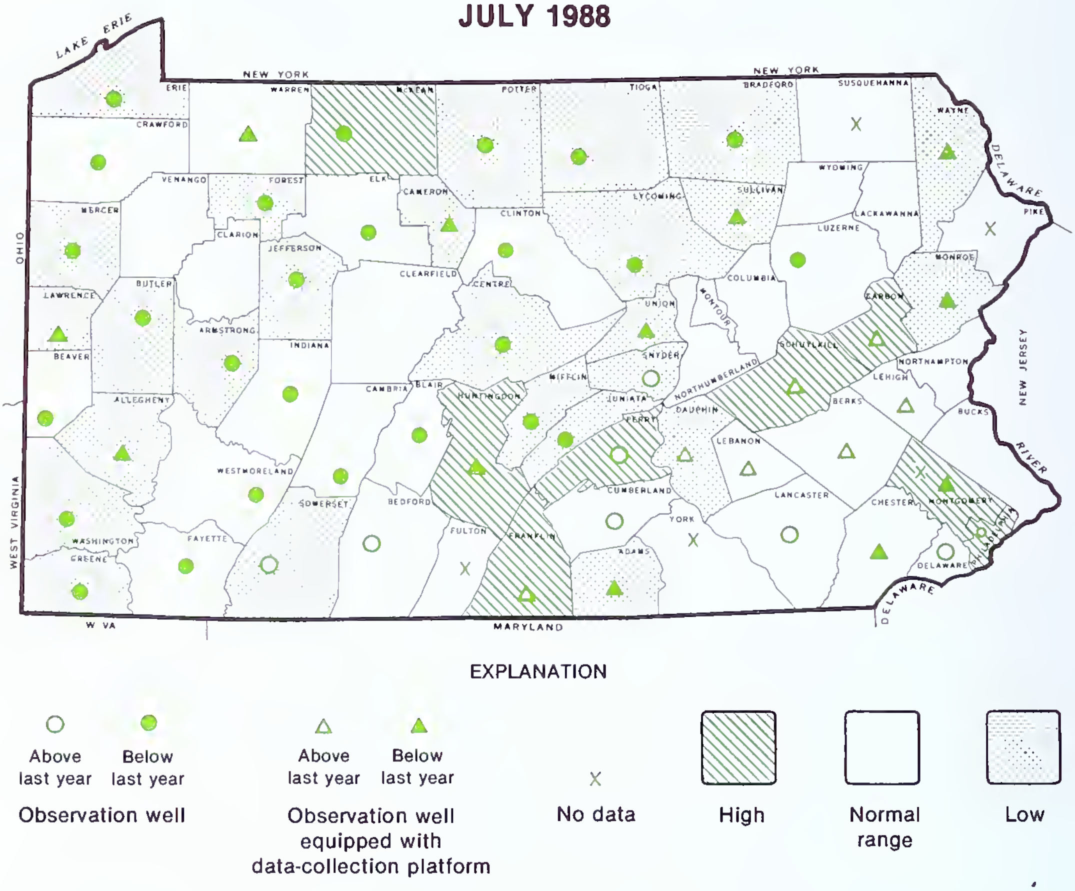

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The Geological Society of America

In December 1888, thirteen geologists gathered at Cornell University in Ithaca, New York, to found a new geological organization, the American Geological Society, later the Geological Society of America, today one of the preeminent societies of geology. Present at the founding were two former members of the Second Geological Survey of Pennsylvania, John J. Stevenson and Israel C. White. The former had been professor and the latter his student, and then both were Assistant Geologists of the Pennsylvania Survey during the period from 1875 to 1883. Of the 112 Original Fellows of the new Society, these two, plus eight others, had been or were members of the Second Pennsylvania Survey, which was in 1888 in the last phases of its remarkable accomplishment of mapping and describing the geology of each of the 67 counties of the Commonwealth.

The seeds of the Geological Society of America were planted in 1834 when Henry Darwin Rogers, later to be the organizer of the First Pennsylvania Geological Survey in 1836, returned from England proposing to his geological colleagues that the United States should have an association similar to the British Association for the Advancement of Science. Rogers, with four other Pennsylvania Survey staff, and geologists from the State Surveys of Delaware, Massachusetts, Michigan, and New York, met in Philadelphia in 1840 to form the Association of American Geologists. Originally only to be an association of geologists, later meetings included other scientists, and in 1843 the group changed its name to the Association of American Geologists and Naturalists. In 1847 it became the American Association for the Advancement of Science, fulfilling Henry Rogers' original intent.

As was the founding of the Association of American Geologists supported by geologists of state geological surveys, so too the founding of the Geological Society of America included support of State Geologists and the geologists of their surveys. Prominent among the Original Fellows of the American Geological Society were the State Geologists of Arkansas (Branner), Georgia (Spencer), Indiana (Collett), Kentucky (Proctor), Michigan (Wadsworth), Minnesota (Winchell), Missouri (Winslow), New Jersey (Cook), New York (Hall), Ohio (Orton), Pennsylvania (Lesley), Tennessee (Safford), and Texas (Dumble). It was through association with the many state surveys, and the newly formed United States Geological Survey, that geologists of the new Society received much of their geological training and practical experience in preparing geological maps and reports.

We celebrate the birth of the Geological Society of America through descriptions of the geological accomplishments of the two Founders and eight other Original Fellows who had been members of the Second Geological Survey of Pennsylvania during the decade of the Society's founding.

Donald M. Hoskins

Donald M. Hoskins
State Geologist

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The Second Geological Survey of Pennsylvania—An Original Supporter of the Geological Society of America

by
Clifford H. Dodge

Although the birth of the Geological Society of America (GSA) in 1888 nearly coincided with the demise of the Second Geological Survey of Pennsylvania (1874–1889), both great organizations shared much in common, not only through their pursuit of excellence in the geological sciences but also because their reputations and achievements resulted from work by many of the same individuals. The Second Geological Survey boasted ten Original Fellows of GSA as having been associated with the Survey in some capacity during its existence. These Original Fellows were C. A. Ashburner, J. C. Branner, E. W. Claypole, Persifor Frazer, Jr., J. P. Lesley, Franklin Platt, J. J. Stevenson, I. C. White, Arthur Winslow, and G. F. Wright. When GSA was founded, these ten ranged in age from 28 to 69. Some were young men just beginning their careers; others were seasoned professionals with national and international reputations; but all shared a common bond of pride and accomplishment in their chosen field. Several of these men held important leadership roles in the young Society, and three, Stevenson (for 1898), Branner (for 1904), and White (for 1920), were elected President of GSA. The early history of GSA has been discussed in detail by Fairchild (1932) and has been reviewed briefly by Eckel (1982). In commemoration of the centennial anniversary of the Geological Society of America, the Pennsylvania Geological Survey is pleased to devote this issue of *Pennsylvania Geology* to articles on each of the ten Original Fellows who contributed to the success of both organizations.

Survey involvement with GSA continued to grow, and during the two years that followed the formation of the Society, six more geologists once affiliated with the Second Survey joined. These six were elected Fellows and included C. E. Beecher, H. M. Chance, E. V. d'Invilliers, W. M. Fontaine, F. A. Hill, and T. S. Hunt. Many other Survey assistants were equally well qualified to join but did not seek admittance owing to advanced age or inclination. Needless to say, the geology of Pennsylvania, its economic importance, and the achievements of the Second Survey were subjects of numerous discussions among early GSA Fellows.

At the time GSA was established, most of what was known about Pennsylvania geology was the result of recent investigations by the Second Geological Survey. The contributions and character of this organization have been discussed recently by Jordan and Pierce (1981) and by Dodge (1987).

The success of the Second Survey depended upon the capabilities of its staff and its mode of operation. In this regard, it is fortunate that J. Peter Lesley was appointed State Geologist. Lesley's outstanding credentials and widespread respect among his peers are evident in an unsolicited letter written in June 1874 from James Hall, later to become the first President of GSA, to W. A. Ingham, a member of the Board of Commissioners responsible for selecting the State Geologist:

> And without disparagement to anyone else, whether an applicant for the place or otherwise, I would beg leave to say that Prof. Lesley's abilities and qualifications for the position are so far superior to those of anyone whom I know that I could not for a moment entertain a doubt of his selection for the place were the matter referred to a number of scientific men.
>
> (Merrill, 1924, p. 694)

In a letter to Governor Hartranft a year earlier, Lesley (1873) responded to the Governor's request for information concerning the proper organization of a state geological survey and stressed the need for hiring well-qualified assistants at a good salary:

> It is no economy to employ inferior talent. Mistakes committed by inexperienced and incompetent persons produce not only waste, but permanent mischief. Men of the best standing in the science would be eager and proud to take part in so great a work.
>
> (p. 9)

> The State should pay well for the best talent, where so much mischief might be done by incompetent persons.
>
> (p. 10)

The many notable (or subsequently well-known) late nineteenth century geologists associated with the Second Survey attest to Lesley's success at attracting highly motivated, capable staff.

Lesley's organization and management of the Second Geological Survey were impeccable. He demanded the highest standards of accuracy and completeness in its geologic and topographic investigations, and emphasized rapid, timely publication of its results. He maintained an excellent rapport with his staff and made certain that they received all due credit for their work. He was forthright and thorough in his dealings with the Pennsylvania Legislature and the Survey's oversight committee, the Board of Commissioners. (See Jordan and Pierce, 1981.)

The work of the Second Survey was empirical and practical, and not theoretical; it dealt primarily with economic geology. Lesley pointed out that

> practically viewed, the geology of Pennsylvania is wholly Paleozoic, on the most magnificent scale, with an unexampled wealth of anthracite and bituminous coal, brown hematite iron ore, limestone, rock oil, and rock gas; and to the study and description of these its geological survey has from first to last been devoted.
>
> (Merrill, 1924, p. 497)

Many of these investigations were particularly accurate and successful. Moreover, the Second Survey systematically examined the rock stratigraphy of the state and established much of the stratigraphic nomenclature still used today. Detailed regional stratigraphic correlations were made in the oil and gas and bituminous coal fields of western Pennsylvania, and truly quantitative geologic mapping commenced during the 1880's in the Anthracite region, which helped unravel the structural complexities of the coal basins. (See Dodge, 1987.) Among its other achievements, the Survey delimited for the first time the terminal moraine of the glaciated areas in the northern part of the state. Even though paleontological investigations were not emphasized, much valuable work was accomplished by several of the assistants. Leo Lesquereux's paleobotanical studies of the coal measures are especially noteworthy and received considerable praise. On the other hand, the major deficiency of the Second Survey was the lack of adequate topographic base maps, a condition caused by legislative failure to appropriate the necessary funding for this kind of mapping (Dodge, 1987).

The Second Geological Survey of Pennsylvania published nearly 120 atlases and volumes, including geologic maps for all 67 counties and one for the entire state. The Survey was innovative in its use of color printing and, beginning in 1883, published some of the first photographs using the newly perfected halftone process. The wealth of maps, drawings, and descriptive information that it produced helped "to uncover with precision the economic mineral resources of Pennsylvania in an age of great industrial expansion" (Jordan and Pierce, 1981, p. 75) and to provide a firm foundation for more detailed studies by industry, government, and academia in the ensuing years.

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◆

Charles Albert Ashburner

by
Clifford H. Dodge

The member of a prominent Pennsylvania family, Charles Albert Ashburner (1854–1889) was born and raised in Philadelphia. He entered the University of Pennsylvania in 1870 at the age of 16 and enrolled in the Towne Scientific School, where he majored in civil engineering. As an upperclassman, he received instruction in geology from J. Peter Lesley, who was then the Professor of Geology and Mining at the University and shortly thereafter State Geologist of the Second Geological Survey of Pennsylvania (1874–1889). Lesley had a profound influence on Ashburner's career, and their years together at the University marked the beginning of a close, lifelong personal and professional relationship.

Ashburner received his baccalaureate in 1874 and graduated valedictorian of his class. He received his Master of Science degree in geology from the same institution three years later, and in 1889, his alma mater awarded him an honorary Doctor of Science degree for his outstanding contributions to Pennsylvania geology.

Ashburner was a superb field geologist and administrator. An applied rather than theoretical geologist, he was a meticulous, systematic, and hard-working individual who, though well aware of his talents and abilities, was not arrogant as some people thought. Ashburner's life and career have been discussed in detail by Dodge (1981).

Shortly after the Second Geological Survey of Pennsylvania was organized in 1874, Ashburner was hired and thus abandoned his career in civil engineering for one in geology. There were few trained geologists in the United States at that time, but Ashburner's superior scientific abilities and experience gained in the field soon eliminated any deficiencies. No doubt because of their growing friendship, the choice of assignments for Ashburner reflected Lesley's particular interests—both geologically and geographically.

Initially, Ashburner and a former classmate, Charles E. Billin, were geologic aides of John H. Dewees, Assistant Geologist in charge of the study of the fossil iron ore (hematite) beds in the Juniata River district of central Pennsylvania. Assignments for the two aides included topographic mapping and investigation of the Silurian and Devonian regional stratigraphy. Within a year, they were promoted to Assistant Geologists and assigned separate districts to examine. In 1875, Ashburner independently studied the geology of Sideling Hill and the East Broad Top coal basin in western Huntingdon County, and published the results of this work three years later (Dewees and Ashburner, 1878).

In 1876, Lesley commissioned Ashburner to survey the important and poorly understood district in northwestern Pennsylvania comprising McKean, Elk, Forest, and Cameron Counties. The famous Bradford oil field of McKean County was then undergoing rapid development and soon was to surpass all other fields in the world in productivity. Although he was to concentrate on the geology of the coal measures and leave the study of oil geology to the Survey's petroleum specialist, John F. Carll, Ashburner's four-year investigation of this district proved to be as important to the understanding of oil as to coal. Moreover, this assignment marked the beginning of his lifelong interest in oil and gas geology.

Charles A. Ashburner, circa 1880.

The results of Ashburner's work in McKean (Ashburner, 1880a, b) and in the other three counties (Ashburner and Sheafer, 1884, 1885) were published in two reports and two accompanying atlases, and still constitute the only comprehensive study of the region. Ashburner used both field observations and subsurface information to establish the stratigraphic relationships of the Upper Devonian and Carboniferous rocks. He successfully correlated the coal seams by recognizing, in part, that the Olean Conglomerate (basal Pottsville Formation) and Vanport Limestone are important key beds in the Pennsylvanian coal measures. The Olean Conglomerate was also used by drillers to estimate the depth to the oil-bearing sandstones, but there was much confusion in distinguishing the Olean from subjacent conglomerates until Ashburner (1880a, p. 57) recognized that "the pebbles in the upper [Olean] conglomerate are invariably round or prolate spheroids (egg shaped); consequently this rock cannot be mistaken for the lower or Sub-Olean conglomerate in which the pebbles are flat or oblate spheroids having the shape of a flattened orange." Among his other contributions was recognition of the rapid southward thickening of the Upper Devonian and Mississippian rocks between the Catskill (Upper Devonian) and Pottsville (Pennsylvanian) Formations, which helped explain why many drill holes failed to penetrate the deeper Bradford oil sand in the southern part of the district. There is no known evidence, however, that he attributed this thickening (or thinning) to a pre-Pottsville regional unconformity, which is now widely recognized.

Appointed in 1881 at the age of 27 as Geologist in Charge of the long-delayed survey of the anthracite coal fields in eastern Pennsylvania, Ashburner undertook his greatest challenge. At that time, anthracite coal was the single most important mining industry in any one state and the third most important one throughout the United States. Ashburner conducted the Anthracite Survey in an efficient, systematic manner; his skill at planning, organizing, and implementing this Survey was his greatest achievement and led to international acclaim for the Second Geological Survey. The Anthracite Survey was a thoroughly modern enterprise: qualified staff were hired; field offices were set up in the main coal fields; numerous contacts were made with representatives of the railroads and coal companies; and an organized system of mapping, colleague review, and publication was established.

Owing to public demand, the Anthracite Survey produced many more atlases than it did "Reports of Progress," which contain detailed descriptive information. The atlases consist of up to five series of sheets including mine maps, cross sections, columnar sections, topographic maps, and miscellaneous maps and charts. The mine sheets were considered by many to be the most important part of the atlases, and they contain a wealth of surface and subsurface information. Especially noteworthy is Ashburner's unprecedented extensive use of structure contours to portray the fold geometry of the coal measures. Use of structure contours not only assisted in planning future mining but also in accurately calculating coal resources. (See Ashburner, 1881; 1883a, b.) Even today, the results of the Anthracite Survey constitute a significant source of detailed geologic information for the region.

In 1885, Ashburner acquired additional responsibilities with his appointment as First Assistant Geologist in charge of general supervision of all Second Geological Survey activities. This was done to allow Lesley time to begin writing a comprehensive "Final Summary Report" on Pennsylvania geology.

However, a year later, Ashburner reluctantly resigned from the Second Survey (though he still worked for it part time) to accept a more lucrative position with George Westinghouse, Jr., in Pittsburgh, and thereafter he became a consulting geologist. Ashburner traveled extensively throughout the United States and Canada, and devoted the rest of his brief career to examining and reporting on new oil and gas fields and, to a lesser extent, on the mining of precious metals and copper. Tragically, two months before his 36th birthday, he fell ill in Arizona and returned home to Pittsburgh, where he died unexpectedly from a kidney infection on Christmas Eve in 1889.

As one of the most distinguished and productive geologists of the Second Geological Survey, Ashburner contributed greatly to our understanding of the Upper Devonian and Carboniferous stratigraphy of Pennsylvania, and much of his work is still valuable today. Despite his heavy work load, he found time to participate actively in many professional organizations. In addition to his status as an Original Fellow of the Geological Society of America (and, sadly, one of the first to die), Ashburner was a member of the American Philosophical Society, American Institute of Mining Engineers, American Association for the Advancement of Science, and many others.

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John Casper Branner

by
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John Casper Branner (1850–1922) was a man of wide-ranging interests and accomplishments. His writings cover topics ranging from geology to biology, and from the Portuguese language to education. Branner was a geologist, biologist, botanist, engineer, interpreter, college professor, State Geologist, and college president. Although his interests and talents were many, he was first a geologist. He was an Original Fellow of the Geological Society of America as well as its president in 1904.

Branner was born on July 4, 1850, and entered Cornell University in 1870, where he met Dr. Charles F. Hartt. Dr. Hartt invited Branner to accompany him on a geologic expedition to Brazil. This trip was the start of a lifelong interest in Brazil and all of South America for Branner; he made numerous trips there throughout his life. His activities in Brazil included geologic mapping, gold mining, and the study of coral reef environments. He also studied insects injurious to cotton crops in Brazil for the U.S. Department of Agriculture, conducted a scientific investigation of the geology and biology near the mouth of the Amazon River, and, in 1880, visited Brazil at the request of Thomas Edison to search for plant fibers that would add strength to incandescent lights. He also studied the Portuguese language.

John C. Branner, 1892.
(Photograph courtesy of the Library of Congress.)

Beginning in 1883, Branner worked as an Assistant Geologist with the Second Geological Survey of Pennsylvania. He worked for two years in the Lackawanna Valley area. This work included topographic and geologic mapping as well as observations concerning glaciation in the region. J. Peter Lesley was State Geologist during the time of Branner's work in Pennsylvania. That Branner fondly remembered the time spent working in Pennsylvania is indicated in a letter to the Academy of Natural Sciences when he received the Hayden Medal. He wrote that Lesley "pointed out the road that every worthy geologist should travel" (Branner, 1911).

Following his work with the Pennsylvania Geological Survey, Branner was appointed professor of geology at Indiana University. He taught there for two years until he was appointed State Geologist of Arkansas in 1887. A primary reason for organizing the geological survey in Arkansas was the excitement caused by the rumored presence of gold and silver in the Ouachita Mountains. Numerous financial deals had been struck prior to an official survey of the area, and excitement was running high among the citizenry. Unfortunately, after a thorough study it was concluded that only insignificant amounts of gold and silver were present in the area. When made aware of this fact, indignant citizens blamed the messenger for the bad news and burned the State Geologist in effigy and demanded his removal from office. Branner stood by his conclusions and weathered the storm created by his first investigation in Arkansas. He continued the survey of the state for about five years and published an amazing 14 volumes before leaving Arkansas for Stanford University in 1891.

Branner taught at Stanford University for seven years before becoming Vice-President of the university in 1899. He was elected President of the Geological Society of America in 1904 and became President of Stanford University in 1913. He remained head of the Department of Geology throughout this time. He was regarded as an excellent teacher and was well respected in the community. John Casper Branner died on March 1, 1922.

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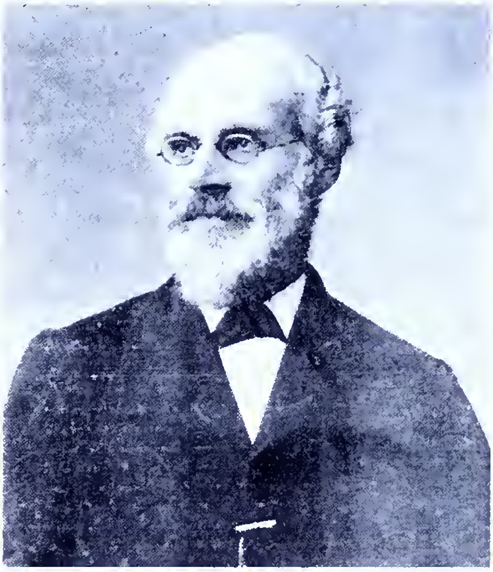
Edward Waller Claypole

by
W. D. Sevon

Edward Waller Claypole (1835–1901), a teacher by profession and an Original Fellow of the Geological Society of America, was employed by the Second Pennsylvania Geological Survey during the years of 1882 and 1883. Commissioned to study the fossils of Perry County, Claypole did much more and made significant contributions to unraveling the geology of central Pennsylvania by more precisely delineating the boundaries of certain units and by recognizing the absence of units previously thought to be present (Claypole, 1885a, p. xi). His report on Perry County followed the general format of other Second Survey reports and included chapters on physical geography, structure, stratigraphy, economic geology, and a separate geological description of each township. In addition, Claypole included items generally not found in Second Survey reports: a geologic history (p. 35–42) and a catalog of the names of plants found in the county during the course of fieldwork (p. 113–145).



E. W. Claypole, circa 1895.
(Photograph reproduced from American Geologist, 1902, v. 29, no. 7, Plate 1.)

Claypole achieved some widespread acclaim as a result of his discovery and reporting of a Pteraspidian fish from the Upper Silurian rocks of Perry County. At the time it was the oldest known fish. He received little recognition for some of his other achievements. Claypole is apparently the first person to calculate the amount of foreshortening (40 percent by his calculation) caused by folding of the rocks in Pennsylvania (Claypole, 1885a, p. 40–41; 1885b). Perhaps even more obscure is the fact that Claypole was one of the first, if not the first, to calculate an erosion rate for the Appalachians (Claypole, 1885a, p. 39–40). His starting value of 8 grains of sediment per gallon of water (160 mg/L) in the Juniata River during ordinary weather and his subsequent calculations leading to an estimated surface lowering of 1 foot in 1,500 years are probably excessive, but the methodology and insight into such processes were at the forefront of thinking at the time.

In addition to the Second Survey county report, the work that Claypole did in Perry County and elsewhere in Pennsylvania resulted in 36 articles and abstracts published in scientific journals. Nor did he restrict his communications to the scientific audience. During his two years in Pennsylvania he contributed to the Perry County Freeman newspaper 30 articles written in popular language. He presumably gave numerous lectures and carried on extensive correspondence during this period because such were always a part of his life. During Claypole's employment by the Pennsylvania Geological Survey, he was a valuable resource for other Survey personnel and is often mentioned in other reports. This period of work in Pennsylvania ended in 1883 because the Pennsylvania Legislature failed to provide money for continuation of the project. Claypole's final paper on a Pennsylvania related topic was published in 1891.

A member of many societies, Claypole was most active in the American Association for the Advancement of Science (AAAS) (Chairman of Section E, 1897; Secretary of Section E, 1886), and both he and his wife were faithful attendees of annual meetings. An editor for *American Geologist* from its inception, his articles appeared most often either in that journal or in the AAAS proceedings. His association with the Geological Society of America, particularly with the Cordilleran Section, was growing at the time of his death.

Edward Waller Claypole, the eldest of six children, was born in the village of Ross, Herefordshire, England, on June 1, 1835. He received a sound education under the tutelage of his father and mother. The firm foundation of classical drill served him well throughout his life in the form of his masterful command of the English language. He received a baccalaureate degree in arts and science from the University of London in 1859 and a doctor of science degree in 1888. A brief teaching career at Stokescroft College was ended when he declined to renounce the hypothesis of evolution. After several years of problems, including the death of his wife, he emigrated to the United States in 1872 and took the chair of natural science at Antioch College in Yellow Springs, Ohio, in 1873. During his Antioch period he remarried and published an unpopular paper on the preglacial origin of the basins of Lakes Erie and Ontario. Following his Pennsylvania Geological Survey experience, he accepted the chair of natural science at Buchtel College, Akron, Ohio, where he remained until 1898. He reinvolved himself in glacial phenomena, continued his prolific work in paleontology, and contributed many articles to the *Daily Beacon* of Akron. In

1898 he took his invalid wife to Pasadena, California, where he accepted a professorship in geology and biology at Throop Polytechnic Institute. He remained there until his death on August 17, 1901.

Further information about Edward Waller Claypole is available in the excellent memorials written by Comstock (1902, 1903), Richardson (1902), and Bridge (1902).

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Persifor Frazer, Jr.

by
Christopher D. Laughrey

In his *Memoir of Persifor Frazer*, R. A. F. Penrose, Jr., well-known benefactor of the Geological Society of America, described Frazer as "a strong man, strong in his intellectuality, strong in his convictions, strong in his capacity to fight, seeking for truth as he saw it" (Penrose, 1910, p. 9). Persifor Frazer (1844–1909) was a Life Fellow in the American Association for the Advancement of Science (AAAS) and the Geological Society of America, and he was one of the Original Fellows of the latter. He was a committee member for the 1884 meeting of the AAAS in Philadelphia, and he subsequently served the AAAS as its representative at the inauguration of the Royal Society of Canada.

Frazer distinguished himself as a geologist and chemist. He was educated at the University of Pennsylvania (A.B. in 1862 and A.M. in 1865), and he studied at the Royal Saxon School of Mines in Freiburg, Germany, from 1866 to 1869. There he passed the State examination in mineralogy in the German language, "with as high a standing as was ever granted a foreigner by that institution" (Harrison and others, 1909, p. 76). Frazer returned to the United

States in 1869 and joined Hayden's national survey party in Colorado and New Mexico as a mineralogist and metallurgist. He remained with the Hayden Survey until 1870, when he began teaching natural history and chemistry at the University of Pennsylvania in Philadelphia, where his father, the eminent chemist John Frazer, was professor of chemistry and vice-provost. At Penn, the younger Frazer advanced to professor of chemistry, and later replaced his father as chairman. He was one of the key figures in the efforts to convince the Legislature to support a second geological survey of the Commonwealth. When these efforts succeeded, Frazer resigned his professorship at Penn and joined the Second Survey.

Persifor Frazer, Jr., circa 1880.

Frazer began his assignment with the Second Survey by initiating reconnaissance mapping in York and Adams Counties, along with adjacent portions of Cumberland and Franklin Counties. During the first two years of his work with the Second Survey, from 1874 to 1876, he presented and published numerous papers dealing with igneous and metamorphic petrology, geochemistry, geomorphology, structural geology, and economic geology. Some of Frazer's work in these areas was particularly significant. For example, Lower Mesozoic diabase rocks in the eastern United States were then considered essentially uniform in mineralogical composition (Dana, 1873). Frazer (1875) compared diabase rocks from the Gettysburg basin and the Hartford basin and, while acknowledging their macroscopic similitude, he documented mineralogical differences between the diabases from the two basins using thin-section petrography. Frazer made considerable use of petrographic procedures in his investigations, and he pioneered several photomicroscopy techniques during the course of his work with the Second Survey (for example, see Frazer, 1876, p. 127–129).

Frazer continued mapping the geology of southeastern Pennsylvania over the next five years. In addition to four Second Survey reports, he published 14 papers concerning Pennsylvania geology in various scientific and technical journals. Most of these papers dealt with the geology of Mesozoic diabase and the economic geology of copper and iron ores in southeastern Pennsylvania. One of Frazer's contributions to the literature during this time was particularly important. In his monograph, *Classification of Coals* (1877), he formally presented and carefully demonstrated the utility of classifying coals on the basis of fuel ratios. Frazer's classification, demonstrated in his paper by numerous examples of Pennsylvania coals, was zealously embraced by Lesley (in McCreath, 1879, p. 144–157). Today it is the accepted coal classification based on rank that is routinely employed by geoscientists.

In 1881, Frazer became General Manager of the iron ore mines of the Central Virginia Iron Company. In 1882 his thesis concerning southeastern Pennsylvania earned him the the degree of Docteur ès-Sciences Naturelles from the Université de France, the first such degree ever awarded to a foreign individual. Frazer continued to publish the results of his work in southeastern Pennsylvania through 1886. Notable among these papers are some of the earliest discussions of the complex geology along the Martic Line—the contact between the Piedmont and Lower Paleozoic sedimentary terrains in southeastern Pennsylvania (Frazer, 1878, 1885).

The remainder of Frazer's career was as distinguished as his years with the Second Survey. In addition to his involvement with the American Association for the Advancement of Science and the Geological Society of America, he was active in the affairs of the International Congress of Geologists and the Franklin Institute. Persifor Frazer accomplished more than most scientific men are able to do in a lifetime. Geology is certainly the beneficiary of his efforts, as was the American Association for the Advancement of Science and the newly founded Geological Society of America.

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J. Peter Lesley

by
Helen L. Delano

"J. P. Lesley, one of the most distinguished and lovable men of science in the United States, was born at Philadelphia on September 17, 1819" (Geikie, 1904, p. xlix). So began Geikie's anniversary address to the Geological Society of London in the year following Lesley's death.

Lesley (1819–1903), who was born Peter Lesley, Jr., but preferred the usage Geikie followed, should be remembered for his scientific contributions, as a prolific author and energetic editor, and chiefly as organizer and director of the Second Geological Survey of Pennsylvania.

His scientific work began in 1838 while working under James S. Whelpley of the First Geological Survey of Pennsylvania in the Pottsville anthracite field. By Lesley's own claim, this was the occasion of the birth of topographical geology, which is the only specialty in which he claimed expertise. In later work in the coal areas of Pennsylvania he continued as a pioneer in the study of the relationship of topography and geology and in the use of both topographic and structure contouring on geologic maps.

J. Peter Lesley, circa 1875.
(Photograph courtesy of the Smithsonian Institution Archives.)

After Whelpley left the Survey, Lesley continued to work in the Pottsville and Pocono areas. He stayed with the First Survey, working also in the bituminous basins in Fayette and Somerset Counties and in several of the northern counties, until 1841.

Lesley, like numerous other scientists of his time, combined interests in geology and theology. He originally studied for the ministry, and after his three years with the First Geological Survey of Pennsylvania, returned to the seminary. He was licensed as a minister by the Philadelphia Presbytery in 1844, and eventually became pastor of a Congregational Church in Milton, Massachusetts.

Between 1841 and 1851 Lesley did occasional drafting and other office work for Rogers' final report of the First Survey, including construction of a geologic map of Pennsylvania. He abandoned the ministry and returned to Pennsylvania and the professional practice of geology, working for Rogers in 1851, and as a private consulting geologist from 1853. His consulting practice contributed much to the study of economic geology of coal, iron ore, and petroleum in Pennsylvania, and included investigations in iron manufacturing technology and coal geology of other areas. His work for the Pennsylvania Railroad in 1853 and 1854 included preparation of what is said to be the first geologic map that had topographic contours.

In 1856 he published *Manual of Coal and Its Topography,* in which he set forth the relationship between structural geology and topography. This was "the first to show how clearly and strongly the topography often indicates the geological structure through the varied effect of the outcrops of underlying basins or saddles of harder or softer rock-beds upon the form of the earth's surface, the mountains, hills and valleys" (Lyman, 1909, p. 464).

Lesley was Secretary of the American Iron Association from 1856 to about 1864, and published *The Iron Manufacturer's Guide,* a standard reference, in 1859. He delivered a series of lectures on *Man's Origin and Destiny Sketched from the Platform of the Sciences* at Lowell Institute, Boston, in 1866. He also served as editor of the U.S. Railroad and Mining Register from 1869 to 1873. He was on the faculty of his alma mater, the University of Pennsylvania, as Professor of Mining from 1859, Professor of Geology and Mining from 1872, and Dean of the Towne Scientific School from 1875 to 1885.

Lesley was chosen in 1874 to become State Geologist of the Second Geological Survey of Pennsylvania. The success of the Second Survey was due in large part to his leadership and management. His emphasis was always on the practical and descriptive aspects of geology rather than the theoretical. His firm belief that the results of the Survey should be immediately and widely available to the public governed his publication philosophy and led to the large number of "Reports of Progress" of the Second Survey, all of which were edited by Lesley. The details of his mode of operation are outlined by Dodge (1988, this volume), and are described in greater depth by Jordan and Pierce (1981) and Dodge (1987).

In the mid-1880's, when the formation of the Geological Society of America from Section E of the American Association for the Advancement of Science (AAAS) was being contemplated, Lesley was near the peak of his professional standing. He was largely occupied with running the Survey, although he turned some of the administrative responsibility over to C. A. Ashburner as First Assistant Geologist in 1885. He somehow found time for an extraordinary level of activity in a variety of scientific societies. Lesley was an active member of the AAAS from 1849, and served as its president in 1884, when he also led a field trip from the Philadelphia meeting to the anthracite country near Schuylkill Gap. At the same time his duties as Librarian and Secretary for the American Philosophical Society continued. That affiliation dated from 1856, and Lesley had edited the Proceedings and Transactions of the Society. As Librarian, he cataloged the library using cards and organized it by a classification system of his own devising. He gave up these duties only to become Vice-President of the Society from 1887 to 1898. He was also a Foreign Correspondent and later a Foreign Member of the Geological Society of London, and a Corporate Member of the National Academy of Sciences.

Lesley's status as an Original Fellow of the Geological Society of America and his affiliations with most of the other scientific societies of the time indicate that he was supportive of the new society and its goals.

J. Peter Lesley spent his last productive years writing *A Summary Description of the Geology of Pennsylvania*, the final reports of the Second Survey. Two volumes and part of a third of this work were finished when his health broke down in 1893, at the age of 74. His life ended quietly in Milton, Massachusetts, in 1903.

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Franklin Platt

by

Albert D. Glover

Franklin Platt (1844–1900) "was a superior man intellectually. He had a phenomenal memory, strong prejudices, and was not easily persuadable. He shunned the society of ladies and emotional influences. He was discreet, politic, and calm in judgment, with a great power of estimating the relative value of things. In person, he was tall and spare, with usually a slight stoop, and of fair complexion." Thus Professor Persifor Frazer wrote of him in 1901.

Franklin Platt, a member of several scientific societies, and an Original Fellow of the Geological Society of America, was born in Philadelphia on November 19, 1844. After attending local schools, he entered the sophomore class at the University of Pennsylvania in 1860, but left at the end of the college year. He served as a private in the militia regiment of Philadelphia, known as the "Gray Reserves," from June 26 to August 1, 1863, when the Confederate Army invaded Pennsylvania. In 1864, Platt received an appointment as an aide on the U.S. Coast and Geodetic Survey, and was one of the topographers under the command of General Poe, who accompanied Sherman's army in its famous "march to the sea."

Franklin Platt, circa 1880.

After the Civil War, Platt studied geology under Benjamin S. Lyman in Philadelphia. Lyman was a nephew of Susan Lyman Lesley, the wife of J. Peter Lesley, who later was to become the State Geologist of the Second Geological Survey of Pennsylvania. In 1870, Platt was associated with Persifor Frazer, who then was teaching natural history and chemistry at the University of Pennsylvania. Frazer also later became a member of the Second Survey.

On July 1, 1874, Franklin Platt was appointed an Assistant Geologist with the Second Geological Survey of Pennsylvania, and was assigned with three aides to the Clearfield and Jefferson District. The report area included all or parts of nine counties and was published as Report H (Platt, 1875). Only a reconnaissance of the area was possible in so short a time. Platt generally agreed with the existing geologic map of the area published in 1858 by the First Geological Survey of Pennsylvania. However, based on his work in Venango County, Platt considered the Tionesta Series (above the Seral of Rogers) of Elk and McKean Counties as mapped by the First Survey to be correlative with the Sharon Series (the Umbral of Rogers), and he deleted the Tionesta Series from his stratigraphic column.

From 1874 to 1881, Platt compiled reports on the geology of the coal basins from Somerset County to the north-central coal fields in Bradford, Tioga, Potter, Lycoming, and Sullivan Counties. He concluded that the coal basins in Sullivan County (Sherwood and Platt, 1880) lay outside or south of the First Coal Basin, an important fact that was missed by the First Survey. He also included several coal analyses in this report, which showed that some Sullivan County coals absorbed water readily after having been dried, and he suggested that such coals may yield inferior coke.

In his earlier reports, Platt listed the Brookville coal, two Kittanning coals, and three Freeport coals in the Lower Productive Measures. In Report T (Platt, 1881b), he changed his classification to agree with the stratigraphy in the Allegheny River sections. As a result, there now were three Kittanning coals and two Freeport coals, the Lower Freeport of his early reports being renamed the Upper Kittanning coal.

In 1880, in response to a legislative mandate, Platt prepared a report on the waste in anthracite mining. In Report A2 (Platt, 1881a), he explained that up to 30 percent of the total anthracite seam thickness could be slate or bone and was thrown out as refuse. He also explained that large blocks of coal called pillars were left to support the roof, and where the roof was bad, the top level of coal was left to support the roof. Finally, he pointed out that coal was lost in breaking, screening, and loading the smaller sizes of anthracite sold for house fuel. He estimated in the report that only 27 to 60 percent of the total seam was shipped to market, the rest having been lost in mining or breaking.

There were indications of Franklin Platt's managerial abilities as early as 1878, when he was placed in charge of the Survey while Lesley attended the International Congress of Geologists in Paris. Then, at a meeting of the Board of Commissioners in 1880, Lesley recommended that "the Anthracite Survey should have an accredited head (Mr. F. Platt) known to all the operators, to inspire their confidence and prevent duplicate applications for data" (Board of Commissioners, 1880).

Platt left the Second Survey on March 1, 1881, when his salary ceased. He did geological work in Nova Scotia, and later that year prepared a report (Platt and Platt, 1881) on the coal lands of the Rochester and Pittsburgh Coal Company in Jefferson County with his brother William, who had resigned from the Survey in July. The Platts considered the coals in Jefferson County to be of superior quality and sought to develop commercial mining there. They were successful in attracting the necessary finances to purchase land, to build a railroad, and to engage a large work force (Cooper, 1982). Coal from the first mine at Beechtree, Jefferson County, was shipped on July 1, 1883.

Franklin Platt helped establish the regional stratigraphy of the Coal Measures for a large area in western and north-central Pennsylvania. He aided in establishing a mapping program in the Anthracite region. He recognized the commercial possibilities of Jefferson County coals, and was one of the founders of a large coal company which is still operating.

He was highly regarded by his peers. The science of geology and the newly formed Geological Society of America benefited from his efforts.

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◆

John James Stevenson

by
Thomas M. Berg

Ever and always student, teacher, and mentor, John James Stevenson (1841–1924) sat faithfully at the knee of Nature, learning about the earth and the dynamic processes that produced what he saw. He was the *observer par excellence.* Professor Stevenson was a tireless educator, beginning at the age of 23, and continuing a lifetime of teaching both in the classroom and in informal and formal communication with his colleagues. As mentor, Stevenson influenced fledgling geologists as well as his own peers. One of his most important professional accomplishments was his persistent and successful motivation and guidance of those who founded the Geological Society of America.

J. J. Stevenson, 1892.
(Photograph courtesy of the Library of Congress.)

Born in New York City on October 10, 1841, J. J. Stevenson began his education at the age of four, and was able to read Greek, Latin, and Hebrew by the age of eight (White, 1925). He graduated from New York University in 1863 as a Phi Beta Kappa. He received his master's (1866) and doctorate (1867) degrees from New York University, and was awarded an honorary LL.D. degree from Princeton in 1893 (Anonymous, 1897). Stevenson was clearly well-read. His earliest lecture notes of 1864 indicate that he had read Lyell's text and the works of many other eminent scientists of his time.

As a student of Nature, his most valuable classroom was the great expanse of the out of doors—the field. Stevenson loved to travel. His early teaching career was punctuated by extensive, detailed geological investigations in Ohio, Colorado, New Mexico, Pennsylvania, Virginia, and West Virginia. His reports for the Ohio and Pennsylvania Surveys, and the reports for the Wheeler surveys west of the 100th meridian, are comprehensive, and reflect the great breadth of his interest and observational ability. Stevenson enjoyed "testing" theories, and probed dynamic processes of nature as he carried out his investigations. His interpretations, deduced from careful observations, were often far ahead of his time. While working in southern Colorado for the Wheeler survey, he correctly interpreted that the present configuration of the southern Rockies resulted from multiple deformational events rather than a single uplift (Stevenson, 1875):

> The Rocky Mountain system, then, is the result of four especially marked upheavals, the first at the close of the Carboniferous, the second at the close of the Trias, the third at the close of the Cretaceous, and the Fourth during the Tertiary.

From the beginning, Stevenson was a student of coal. In his very first geology lectures, he said: "The deposit of coal was the great epoch in the history of the earth . . . Hence it is that coal stands as a boundary of high animal life on one side, and of low animal life on the other. Therefore it is the great epoch in geological history" (Stevenson, 1864, unpublished lecture notes). He examined peat and coal in his travels throughout the Appalachians and the Rockies, and in Europe, especially France. He read and evaluated every conceivable paper and document on coal and coal formation. Stevenson's treatises on the Carboniferous of the Appalachian basin (1903, 1904, 1906, 1907) and on the origin of coal (1911, 1912, 1913) still stand as monumental works to be read and absorbed by students of coal geology today. In his last major treatise on coal titled *Interrelations of the Fossil Fuels*, he gave an indication of the depth of his investigation (Stevenson, 1916, p. 21):

> In preparing for these studies, the writer has travelled scores of thousands of miles in foreign regions . . . and, in this land, he has made examinations in almost all of the coal-producing states. But life is short and distances are great; . . . to secure the knowledge necessary for intelligent discussion of the subject, [one] must collect and compare . . . the observations reported by others. This has been attempted; several thousands of reports, notes, memoirs, and monographs have been read and . . . digested, in so far as they contained matter bearing on the problems at hand.

Stevenson's insatiable thirst for learning clearly spread to his students. His deep-set eyes and strong brow evinced a determination to find the truth and reveal it with candor. "His students loved and trusted in him, because they knew he was master of his subject and possessed sympathy and the 'milk of human kindness' for them" (White, 1925, p. 103). I. C. White claimed (1925) that had it not been for the teaching influence of Stevenson, he might have continued preparing for a career in medicine. Stevenson taught at West Virginia University from 1869 to 1871, and accepted the chair of geology and natural history at New York University in 1871, remaining on the faculty there until retirement. He was secretary of the faculty at New York University from 1886 to 1888, and under his management the science courses were significantly amplified, and the geological museum was built up largely through his contributions (Anonymous, 1897). Stevenson retired from teaching in 1909, but he continued to be deeply concerned about the quality of education: "A graduate should show full knowledge of his responsibility as a man, should have learned the importance of prompt, honest performance of his work, whatever it may be; should be able to think clearly; should have acquired knowledge and the ability to utilize it" (Stevenson, 1921, p. 422).

Stevenson's vast knowledge, invaluable acumen, and unique capability as teacher readily equipped him to be mentor for individuals and for organizations. He spoke out for excellence in teaching and just compensation: "The office of professor should be restored to its former dignity; it should be regarded as all-important, and college should become a place for study, not for play; a place where faithful students will be honored" (Stevenson, 1915, p. 31). As mentor for his geological colleagues, Stevenson rendered an enormous service by doing most of the critical organizational work when the Geological Society of America was founded. He was among the original 13 founders, and was Secretary of the Committee of Organization in 1888. Of his efforts, White (1925, p. 100) said:

> At that date in the history of geologic science there were many personal differences and antagonisms among American geologists, which required the greatest tact and skill as a harmonizer to secure the necessary cooperation and support for the new organization in order that its success might be assured. This difficult task was solved in a masterly way by Secretary Stevenson . . .

Ten years after the founding of the Geological Society of America, then President of the Society, Stevenson said (1899, p. 91): "We close our first decade justly gratified by success and full of hope for the future . . . In not a few instances misunderstandings have been removed and coldness or suspicion has been replaced by personal friendship."

In his lifetime, especially in his later years, Stevenson was a mentor for society at large. He held strong conservative views, and was a champion of hard work and earned freedom. He regarded socialism, communism, and even organized religion as failures. He placed his greatest hope in learning (Stevenson, 1922, p. 250): "Education is urged by many and without doubt, its defenders are right, for the only means of relief is in some training which will enable men to see things as they are." John James Stevenson died on August 10, 1924.

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Israel Charles White

by

John A. Harper

Israel Charles White (1848–1927) was a student and protégé of John J. Stevenson. Both were present at Cornell when the Geological Society of America was founded. White, a native West Virginian, had originally intended being a physician; however, he developed a keen interest in geology when he took Stevenson's geology course at West Virginia Agricultural College (now West Virginia University). After graduating in 1872, White spent two years teaching public school and preparing research papers in geology. Stevenson was very impressed by his former student's abilities and published work. In 1875, when Professor Stevenson was hired as an Assistant Geologist for the Second Geological Survey of Pennsylvania, he quickly selected White to be his field assistant.

With Stevenson, White began the task of identifying, correlating, and mapping the various coal seams exposed in the area of Pennsylvania lying south of the Ohio River and west of the Monongahela River. When the work was accomplished, State Geologist J. P. Lesley was so impressed with White's work that he promoted the young man to Assistant Geologist and assigned him the task of mapping the geology and coal resources of the counties bordering Ohio north of the Ohio River.

I. C. White, circa 1880.

White did an enormous quantity of work, spending summers in the field and then writing his reports after returning to West Virginia University, where he began teaching in 1877. In his report on Lawrence County, he pointed out a major problem of miscorrelation between western Pennsylvania and eastern Ohio stratigraphy. In his report on Erie and Crawford Counties, he confirmed the lack of large coal reserves in those areas, and provided evidence that the Venango Third oil sand of drillers in Venango County was the same rock unit as the nonproductive sandstone quarried for building stone in Erie. When his work on western Pennsylvania was finished, White was assigned to map the geology and mineral resources of the eastern counties bordering New Jersey. Because of the perceived lack of valuable mineral resources in the eastern Pennsylvania area, the main results of White's work were stratigraphic in nature.

As a result of his work in northwestern and northeastern Pennsylvania, White made several significant observations on glacial geology. His contributions may have been more notable, however, were it not for Lesley's quick hand in editing manuscripts. In at least two cases White proposed explanations for buried glacial valleys that Lesley excised from the published Second Pennsylvania Geological Survey reports. For example, White proposed an interesting concept to explain the differences in the deeply buried valley of the Susquehanna River on opposite sides of the terminal moraine near the Columbia-Luzerne County boundary. White maintained that this glacial valley disappears at or near the moraine and proposed that the weight of the ice sheet and its sediment load depressed the earth's crust to a greater extent than in those areas south of the ice movement. Lesley, unimpressed with new explanations, deleted White's speculation and published in its stead an editor's note (Lesley, in White, 1883, p. 27):

> I omit from this report the conjectures to which the facts above mentioned give rise, because they have neither scientific nor practical value. Until we have obtained more facts it is useless to indulge in vague speculations concerning causes.

White later complained that his "brilliant discovery in *isostacy* even before that word was coined, died at a few strokes of Dr. Lesley's unsparing 'blue pencil'" (White, 1923, p. 335).

Probably White's greatest contribution to geology was the revival of interest in the anticlinal theory of oil and gas accumulation first published by Hunt (1861). The original theory gained little attention and support, mostly because Lesley vehemently opposed it. Lesley was well aware from the work of Second Pennsylvania Survey geologist John F. Carll that the best producing fields in Pennsylvania were situated in areas of little or no structure. With his power as State Geologist in the world's leading oil-producing area he proceeded to undermine the theory until it was nearly forgotten. White (1892) restated the theory after successfully demonstrating its value to oil and gas exploration by applying it to the discovery of the Mannington oil field in West Virginia. The "anticlinal theory" is still one of the most highly regarded and relied upon concepts in the petroleum industry today.

White worked for the Second Geological Survey of Pennsylvania from 1875 until 1883. During that time he authored or coauthored nine volumes of Survey reports on geology and paleontology, and established for himself a reputation as an outstanding scientist, educator, and original thinker. From 1883 until 1888 he spent his field seasons working for the U.S. Geological Survey. He taught at West Virginia University from 1877 until 1892, when he left to go into private business. White was quite successful in consulting and was well known as a shrewd businessman. He charged large fees for his services and quickly became quite wealthy. He was a recognized expert in geology and mineral-resource exploration and evaluation; he consulted on numerous projects in the United States and Mexico, and spent the years 1904 to 1906 in service to the Government of Brazil performing a survey of coal and petroleum resources. He organized and served as the first head of the West Virginia Geological and Economic Survey from 1897 until his death in 1927, and for all but two years of his tenure he refused to accept any form of remuneration.

White was involved in a large number of civic and professional organizations, including the Kiwanis Club, the Association of American State Geologists, and the American Association of Petroleum Geologists. He served as Vice-President of the American Association for the Advancement of Science, and as Chairman of Section E, Geology, during the period 1906–07. One of the founding members of the Geological Society of America, White devoted much of his time and resources to keeping the Society operating successfully. He was President in 1920, but his greatest role was as Treasurer, a post he held for 15 years (1892–1907). During that time he built up a publication fund of over $10,000, while refusing to accept reimbursement for his services or for expenditures he incurred. I. C. White was generous to his profession, and at the time of his death he was widely admired and highly regarded by his peers and his fellow West Virginians alike.

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❀

Arthur Winslow

by
Sandra D. Blust

Arthur Winslow (1860–1938) came to the Pennsylvania Geological Survey in 1881, "almost immediately after graduating from the Massachusetts Institute of Technology, where I had enjoyed the inspiration of contacts with Wm. B. Rogers, who was then still directing the affairs of the Institute. To go from him to the field of work of his talented brother, Henry D. Rogers, was an auspicious introduction to my chosen field of work" (Winslow, 1936). He spent the next three years compiling the maps of the anthracite fields of northeastern Pennsylvania.

In 1936 when George Ashley, then State Geologist of the Fourth Survey, invited Winslow to the centennial reunion of Survey workers he replied that, though unable to attend for reasons of health, he sent the following remembrances of his association with the Pennsylvania Survey.

> My work while in the survey was of a quite subordinate character, first with H. M. Chance at $60.00 per month, principally in drafting for his report on mining methods, and later with C. A. Ashburner on the mapping of the anthracite fields. I was connected with the Survey from 1881 to 1884, and it was to me a very interesting experience. . . .
>
> My first location was at Wilkes Barre, that then small place in the beautiful Wyoming valley. My work there was, principally, in the office, over the draughting board, varied by descents underground into the great coal mines of the vicinity. . . .
>
> I made various excursions and reconnaissance all over this region, generally on foot, climbing its rugged hills through the thick underbrush, following outcrops and what not. . . . Among other projects I made a geological cross section on foot down the Lehigh River, using the railroad as a base line and counting the rails between outcrops. At one time I conducted a vernier survey from Drifton to Pottsville in order to tie together the central and southern coal fields. . . .
>
> An amusing incident I remember occurred in Wilkes Barre, where an astronomical observation was conducted by Prof. Doolittle of Lehigh University, I believe, to determine the exact latitude and longitude of that place as a check on our mapping. When the work was completed the professor made his report, a monument was erected in the court house yard with the figures of latitude and longitude inscribed thereon, as the official result of the observation of the Second Geological Survey. Hardly was this exposed to public scrutiny than caustic criticisms appeared. One correspondent to the local paper denounced the results as grossly inaccurate, stating that he could give a better longitude result with his grandfather's old turnip watch. Great was the furore aroused. Ashburner rushed hot foot and indignant to the scene. An investigation followed. The explanation developed that the figures transmitted by Prof. Doolittle had been expressed by him in hours, minutes and seconds, and these had been groven on to the monument as *degrees*, minutes and seconds. Great was the humiliation that followed, and hasty veiling of the monument for erasures and correcting.
>
> (Winslow, 1936)

Ashburner used stadia measurements for most of the field surveys in the Anthracite District. Because mining engineers questioned the accuracy of stadia measurements, Ashburner asked Winslow to prepare a description of this theory and application. Winslow's report was published as Appendix B to Ashburner's 1883 report on the eastern end of the Southern Anthracite field (Winslow, 1883, p. 325–326, footnote).

Arthur Winslow, 1892.
(Photograph courtesy of the Library of Congress.)

Following his work in Pennsylvania, Winslow did consulting work in North Carolina and Arkansas. While in Arkansas he also served as a member of that state survey, and again was a colleague of John C. Branner (Winslow, 1936). In 1888, the year in which the Geological Society of America was founded, Winslow became State Geologist of Missouri and served until 1894. He was among the 13 State Geologists named as Original Fellows of the Geological Society of America (Geological Society of America, 1889, p. 583). Winslow returned to consulting after 1896 and was engineer, business manager, and later president of Liberty Bell Gold Mining Company. Winslow's bibliography, compiled by Alfred C. Lane (1939), includes mainly notes and articles concerning mapping techniques and mineral deposits of the various states.

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❦

George Frederick Wright

by
Rodger T. Faill

The terminal moraine of the Wisconsinan glaciation brought George Frederick Wright (1838–1921) to Pennsylvania, working as a geological volunteer for the Second Survey for several months in 1881. His vocation was theological, but his inquiring mind and archeological interests drew him into glacialogy. Although the quantity of work he did for Pennsylvania was marginal, his cooperative efforts with Professor H. Carvill Lewis contributed significantly to Report Z, *Report on the Terminal Moraine in Pennsylvania and Western New York*. As J. P. Lesley wrote in his letter of transmittal to Governor Pattison, "the report . . . is greatly enhanced by the fact that two good observers checked and verified each others' observations at almost every point" (Lesley, in Lewis, 1884, p. vii).

George Frederick Wright was trained for the clergy. After graduating from Oberlin College in 1859, he entered the Oberlin Theological Seminary. With the outbreak of the Civil War in 1861, he enlisted with the Seventh Regiment of Ohio volunteers, but a bout of pneumonia shortly thereafter ended his military participation. Graduating from the Seminary in 1862, Wright became a Congregational pastor, first in Bakersfield, Vermont, and after 1872, at the Free Church in Andover, Massachusetts. In 1881, he returned to the Oberlin Theological Seminary as a Professor of New Testament Language and Literature, a position he held for 26 years until his retirement in 1907.

G. Frederick Wright, circa 1890.
(Engraving reproduced from Popular Science Monthly, 1892, v. 42, preceding p. 258.)

Wright had no formal geological training. Bakersfield, Vermont, sits on a sandy outwash plain and has eskers nearby. These attracted Wright's attention, and he went on to study the remarkable eskers and kames around Andover and surrounding areas in northeastern Massachusetts. His publications drew the attention of J. P. Lesley, who hired Wright in 1881 to work closely with Lewis in mapping the glacial terminal moraine that stretches across northern Pennsylvania. With encouragement from friends in Ohio, Wright continued tracing the terminal moraine from Pennsylvania across Ohio and Indiana into southern Illinois. He was commissioned in 1884 by the U.S. Geological Survey to complete his mapping westward to the Mississippi River. It was during these studies that he developed the idea of an enormous ice dam across the Ohio River at Cincinnati which created a 20,000-square-mile lake during the Illinoian glacial stage.

Wright began soon thereafter his excursions to other parts of the world to study present-day glaciers. In 1886, he traveled to Alaska, making a survey of the Muir glacier, in which he established that it had retreated 20 miles since it had been discovered a century earlier. In 1892, he visited Alpine glaciers and numerous archeological sites in western Europe. Two years later, he studied glaciers in southern Greenland. In addition to two subsequent trips to Europe, Wright traveled around the world, passing through northern China, Siberia, and Turkestan. It was from this trip that he concluded that Pleistocene continental glaciation had never covered central and northern Asia.

Throughout his active professional life, George Frederick Wright published extensively on the results of his studies and travels. He was also actively involved in editorial responsibilities for several journals. In addition, he combined his theological training and his archeological and geological experience in a long-continued attempt to understand the antiquity of early man.

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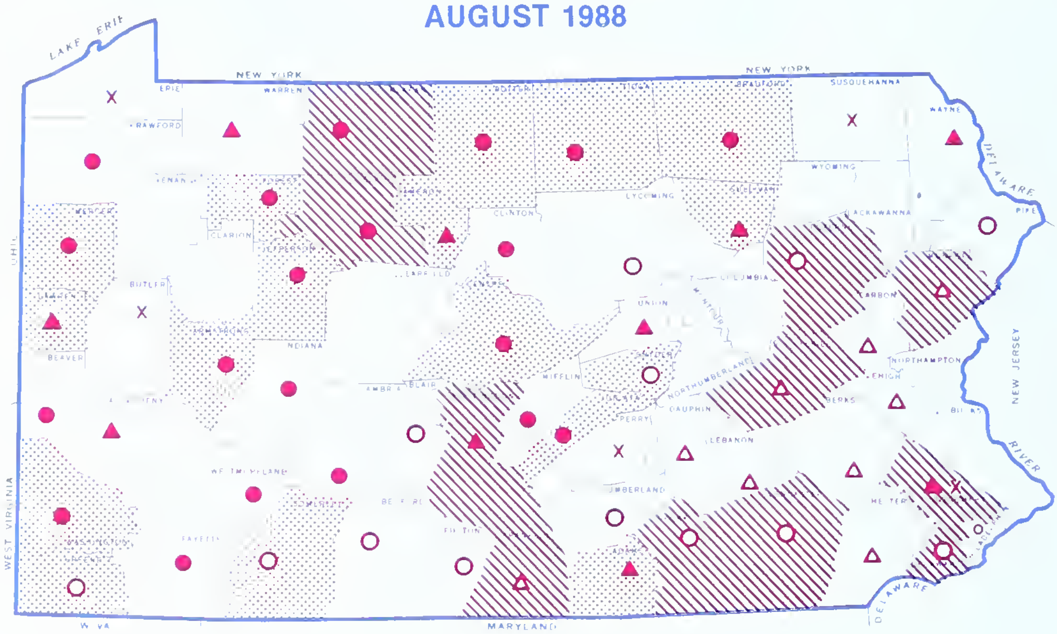

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Donald M. Hoskins, Director

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ON THE COVER: Snow-covered waste piles and breaker ruins at the site of the long-abandoned Beaver Brook Colliery, along Pa. Route 309 about 3 miles south of Hazleton in the Eastern Middle Anthracite field. Photograph by Jon D. Inners.

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On Behalf of the Future—Trees and Geologic Maps

Dr. Maurice K. Goddard, for many years Secretary of the Department of Forests and Waters, later Environmental Resources, in a speech on managing natural resources, stated that, in forestry, the planting of trees is on behalf of the future.

And so it is with geologic maps. Just as much as we need trees in the future to maintain and support the quality of our environment, so, too, our society demands geologic maps to locate and manage the resources increasingly being used in our daily lives. It is through use of these maps that the mineral, energy, and water resources needed by future generations will be discovered. There is no other way! We must live on this earth and use its resources effectively for the benefit of all. The water resources needed for daily life and the energy used to heat and cool our houses will not come from the stars!

The geologic maps that were produced by our geologists of the past generation are extensively used today to support our population's natural resource needs and to plan where to dispose of the wastes that modern society generates. The next generation's needs will be even greater for the geologic maps we "plant" today.

Geologic maps are expensive to create. They require long years of data collection, sampling, and analysis. But when completed a geologic map portrays the rocks and surficial materials underlying Pennsylvania in a manner usable by many diverse groups for many purposes: the mineral explorers seeking new resources, the driller seeking water for a home, the engineer needing stable land on which to build, the planner seeking to provide for our population's inevitable expansion, and surely purposes yet unforeseen. This investment in the future is an absolute requirement if we are to continue to provide for the welfare of our citizens that derives from the use of natural resources.

Planting trees and creating geologic maps is on behalf of Pennsylvania's future. They are a commitment on the part of foresters and geologists in the belief that we can do nothing less.

Donald M. Hoskins

Donald M. Hoskins
State Geologist

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DOCUMENTS SECTION

For Thirsty Tourists— A New Well

by Thomas A. McElroy
Pennsylvania Geological Survey

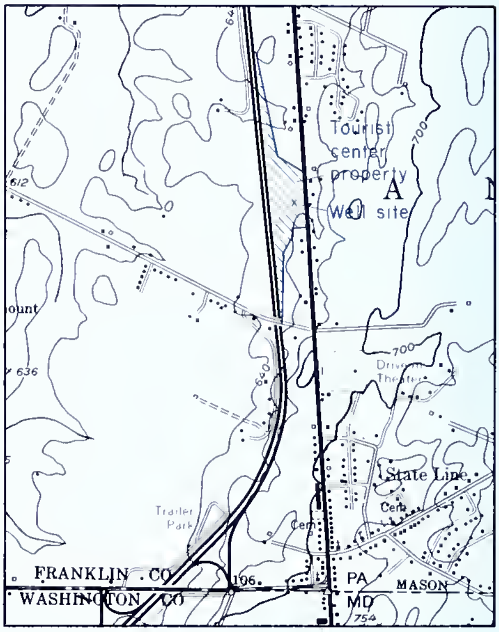

Figure 1. Location of the proposed tourist center in Franklin County, and well site.

As part of an effort to promote tourism in Pennsylvania, Governor Casey has directed that tourist centers be constructed at major entries into the Commonwealth. One such entry is in Franklin County, where Interstate 81 crosses into Pennsylvania (Figure 1). In the 1960's, land was acquired for the purpose of construction of a center. However, two wells drilled on the property in 1970 failed to produce a sufficient supply (25 gpm [gallons per minute]) for the center, and construction plans were abandoned. In 1987, in keeping with the governor's directive, the Pennsylvania Department of Transportation (PennDOT) decided to make another attempt at locating an adequate water supply on the site. The Pennsylvania Geological Survey was contacted to determine if there would be a reasonable possibility of drilling a well to supply the center and, if so, to site test-well locations. The Survey located a well that allowed the tourist center to be built.

The area is underlain by the Rockdale Run Formation, an Ordovician-age limestone containing dolomite interbeds and some chert. Well siting in such carbonate rocks is a challenge for hydrogeologists, as most significant flows of groundwater are from solution-expanded fractures, which can be difficult to locate and exploit. Because of these difficulties, more than 75 percent of the wells drilled for large supplies in the carbonates of the Cumberland Valley in Franklin County are abandoned as unsuccessful (Becher and Taylor, 1982). A commonly applied technique for determining a well location in carbonate rocks is to use fracture traces, which are thought to represent surface expressions of nearly vertical zones of fracture concentrations (Lattman and Parizek, 1964). However, of the two wells located by this technique in 1970, one was dry and the other yielded only 1 gpm.

A new on-site inspection of the undeveloped property revealed another fracture trace and a small sinkhole. Three new test-well sites were selected, two on the newly found fracture trace, and one north of, and on strike with, the sinkhole. On January 25, 1988, a well was drilled to 200 feet at the site adjacent to the sinkhole (Figure 1). The well yield was estimated at 60 gpm, and the water entered the well bore through a void between 96 and 98 feet. It soon became evident that the well was hydrologically connected with the sinkhole; muddy water blown out of the well by compressed air on the drilling rig was running down the sinkhole and was apparently reentering the well, which prevented the well water from clearing. A pump was installed in the well, and the water was piped away from the sinkhole. Within an hour the water cleared, and only 1 foot of drawdown was recorded after 5 hours of pumping at 35 gpm. Accordingly, PennDOT decided to convert the test well to a production well, and a formal 48-hour pump test for certification by the Department of Environmen-

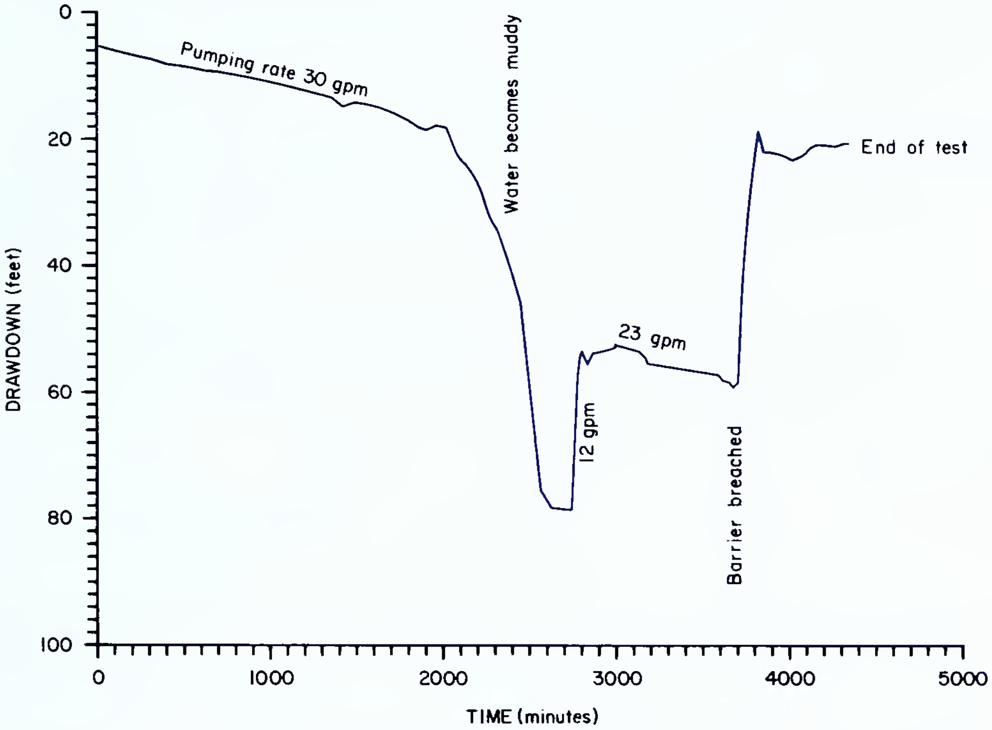

Figure 2. Drawdown curve for the pump test at the tourist-center well site.

tal Resources was scheduled. Figure 2 is the drawdown curve for the test, which was extended to 72 hours. The curve shows a response to pumping that is far from normal. The water level first slowly declined, then sharply declined (with attendant turbidity of the groundwater), rose due to a reduced pumping rate, slowly declined again, very sharply rose, and, at the end of the test, held relatively steady.

Why did this happen? The response to pumping of the well is a consequence of characteristics of the solution-expanded fractures in carbonates through which groundwater moves. Spelunkers observe that most undeveloped caves have large volumes of mud in the passageways, and that sometimes the mud will completely fill an opening. It was concluded that the opening in the well for the tourist center through which groundwater is transmitted also had mud coating it, which caused the initial turbidity. This mud was pumped out during the initial pumping of the well. During the 72-hour test, groundwater was drawn in further and further from the well, primarily through the opening 96 feet below surface. The opening probably has the same north-south orientation as the strike of the bedrock. The sharp decline of the drawdown curve and attendant turbidity indicate that a mud plug, located in the fracture connected to the opening, was encountered as the cone of depression expanded. The plug constituted a negative boundary; water could not pass through it, and thus water production from the plugged end of the opening ceased, which caused the sharp decline in water level in the well and necessitated a lowered pumping rate. During the course of the pump test, the mud plug was breached, which allowed groundwater once more to pass through the opening, causing a rise in water level.

The tourist-center well is an excellent example of problems that can be encountered in locating and developing a high-capacity well in carbonate terrain. Following successful development of the well, in October 1988 funding was approved for construction of the tourist center.

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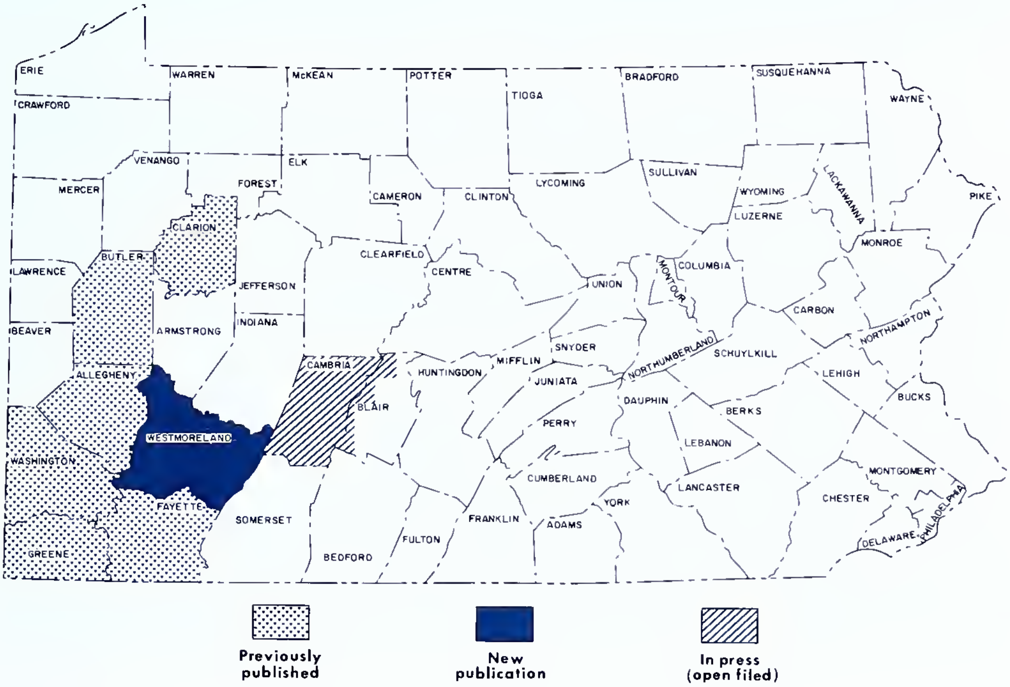
NEW COAL RESOURCE MAPS PUBLISHED BY PENNSYLVANIA GEOLOGICAL SURVEY

Extensive research of mining and drilling records, and several years of field work have resulted in the seventh in a series of county maps showing the distribution of Pennsylvania coals. The Pennsylvania Geological Survey has recently published Mineral Resource Report 94, **Coal Resources of Westmoreland County, Pennsylvania—Part 1, Coal Crop Lines, Mined-Out Areas, and Structure Contours,** by Viktoras W. Skema. The report covers minable coal seams within all or parts of thirty-three 7.5-minute quadrangles in the county. The quadrangles have been photographically reduced to a convenient but readable 8½- by 11-inch size (about 1:62,500 scale), and fit neatly into a three-ring binder. There are separate maps for each coal seam within a quadrangle showing surface outcrop lines and all mined-out areas. Separate patterns on the maps distinguish deep-mined areas from surface-mined areas. A summary map for each quadrangle shows all of the coal seam outcrop lines together, and geologic structure contour lines in a different color. The structure contours show how the coals and coal-bearing strata are warped into broad upfolds and downfolds (anticlines and synclines).



Because Appalachian coals are so often characterized by lateral discontinuities, the author had to carefully analyze and correlate hundreds of measured field sections and drilling records that he obtained. The resulting maps are the most up-to-date and accurate delineation of the coals for Westmoreland County. Because the coals are the key geologic beds in western Pennsylvania, the maps are also a bonus for many other users in addition to coal producers. Most of the other mineral resources and aquifers in Westmoreland County can be located in reference to the coal seams. Beds of limestone, claystone, shale, and sandstone can be identified by their vertical separation from the key coal beds.

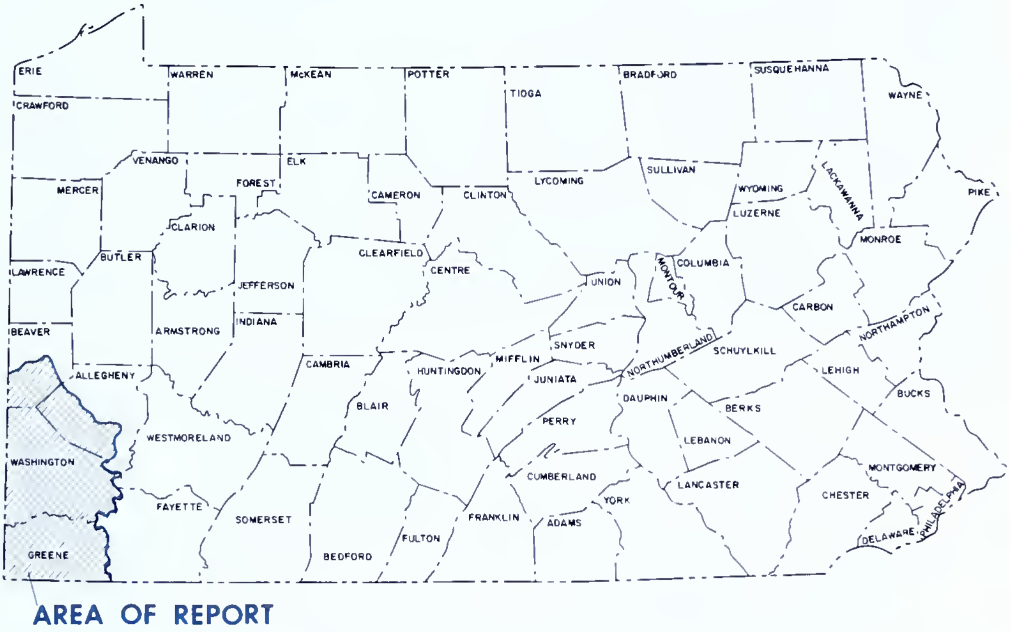
Mineral Resource Report 94 is available from the State Book Store, P. O. Box 1365, Harrisburg, PA 17105. The price is $14.55, plus 6 percent state sales tax for Pennsylvania residents. All orders must be prepaid, and checks should be made payable to *Commonwealth of Pennsylvania*.

OIL AND GAS POTENTIAL OF SOUTHWESTERN PENNSYLVANIA IS HIGH ACCORDING TO NEW REPORT

Southwestern Pennsylvania has had a rich and interesting heritage of oil and gas exploration and development during the past 100 years. For example, in 1892 crude oil production in the area south of the Ohio River and west of the Monongahela River (see location map) amounted to 13,403,724 barrels, or 49 percent of the total state production that year. Declining production and competition with the coal-mining industry for leasing of land slowed exploration and drilling. Thus, in 1987 the area produced less than 6 percent of the state total. Production on a per-well basis also declined. Although no recent by-county records exist for natural gas, production of this resource has probably followed the same trend.

Despite a decline in drilling, completion, and production, some of the oil and gas fields of southwestern Pennsylvania have relatively high estimated reserves because of early abandonment. Recent reserve estimates for the area are low because few new discoveries have been made since the early 1900's. Realistically, the low estimates of oil and gas reserves are probably due more to a lack of new information than to declining reserves.

To stimulate interest in the area, the Pennsylvania Geological Survey has published Mineral Resource Report 87, **Geology of the Oil and Gas Fields of Southwestern Pennsylvania**. This well-illustrated report contains information on the stratigraphy, petrology, source beds, thermal history, structure, and drilling and production history of the area. Both conventional and unconventional hydrocarbon resources are analyzed, and it is concluded that there is still a great deal of potential for recovery of oil and gas in this traditionally ignored area of Pennsylvania. Through this report, the authors, John A. Harper and Christopher D. Laughrey of the Survey's Oil and Gas Geology Division, hope to rekindle interest in this area as well as to present some new data that will be of use in exploration and production throughout much of western Pennsylvania's oil and gas area.



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Strange Clay Baffles Geologists

by Robert C. Smith, II, Samuel W. Berkheiser, Jr., and John H. Barnes, Pennsylvania Geological Survey, and Donald T. Hoff, State Museum of Pennsylvania

Several years ago, scientists discovered that a layer of clay found at the boundary that marks the end of the Cretaceous Period, about 65 million years ago, is distinguished by an unusual enrichment of the element iridium (Ir). This clay layer has been found at locations all over the world, leading to speculation that the Cretaceous Period, and the "Age of Reptiles," was brought to a dramatic end by a gigantic meteorite impact that threw huge amounts of debris into the atmosphere, blocking the sun for months before raining down on earth to form this layer. The meteorite would be the source of the iridium.

Although some evidence from the study of fossils now suggests that the end of the "Age of Reptiles" might have already started before such an impact, the evidence that the impact did take place has led scientists to look at other boundaries in geologic time when many plants and animals became extinct and were replaced with new species.

MESOZOIC TIMES
Strange Clay Baffles Top Scientists!
Fashion: skin and scales out, fur and feathers in
Volcanic Eruptions Predicted
The End is near! Heavenly bodies sighted!
Egg-sucking mammals on the loose!

You know, it's getting so you hate to look at the paper anymore!

One of these boundaries is that between the Triassic and Jurassic Periods, dated at about 200 million years ago. Olsen and others (1987) and Raup and Sepkoski (1986) reported that many life forms became extinct at this time. Cornet (1977) indicated that this boundary was accessible in Berks County, near Jacksonwald, where he reported that it could be found within a 20-m stratigraphic interval, based on the presence and abundance of particular kinds of fossil spores and pollen. Knowing that the site would soon become inaccessible because of development, we could not resist taking a look while it was available.

Within the 20-m interval believed by Cornet (1977) to contain the Triassic-Jurassic boundary at Jacksonwald, we found a complex, half-meter-thick zone of mostly gray siltstones in a sequence of predominantly red siltstones and mudstones that were deposited in the beds of lakes and playas. What makes this zone so intriguing is that it contains a geochemically peculiar, light-colored clay layer.

At Jacksonwald, Cornet's sample JB6 (Figure 1) was reported to contain Late Triassic assemblages dominated by conifer pollen. Up to 99 percent of the pollen in his next higher sample, JB4, is of a different type and is reported to be Jurassic, suggesting that the Triassic-Jurassic boundary must lie in the 20-m interval between them. In an attempt to reexamine the section observed by Cornet, the authors hand dug and measured the section shown in Figure 1. This interval was described from a temporary trench located 415 m east of Antietam Creek and begins about 4 m below the base of the Jacksonwald basalt (Wherry, 1910), a surface flow of the York Haven diabase.

Based on its sticky feel and grayish-white color, and the presence of *Equisetum* (horsetail) plant casts, a 2-cm-thick clay layer, designated R5A, attracted attention in the field and was mineralogically and geochemically analyzed in the laboratory. Besides containing a distinctive coaly layer at the top, it contains major amounts of smectite (swelling clay) as well as quartz and clay-mica. Minor quantities of both plagioclase and potassium feldspar are also present. A Sr/Rb ratio of about 0.5 suggests that it is not a leached, limy clay. With 25 parts per billion (ppb) platinum (Pt) (Table 1) and 15 ppb gold (Au) (Table 2), a meteorite contribution might at first be suspected for the R5A layer because meteorites are enriched in Pt and Au. However, reliable analyses for other platinum group elements, such as Ir, which are contained in larger amounts in meteorites than in most crustal rock of Earth, were all below detection limits using sensitive techniques, effectively ruling out a cosmic origin for the R5A

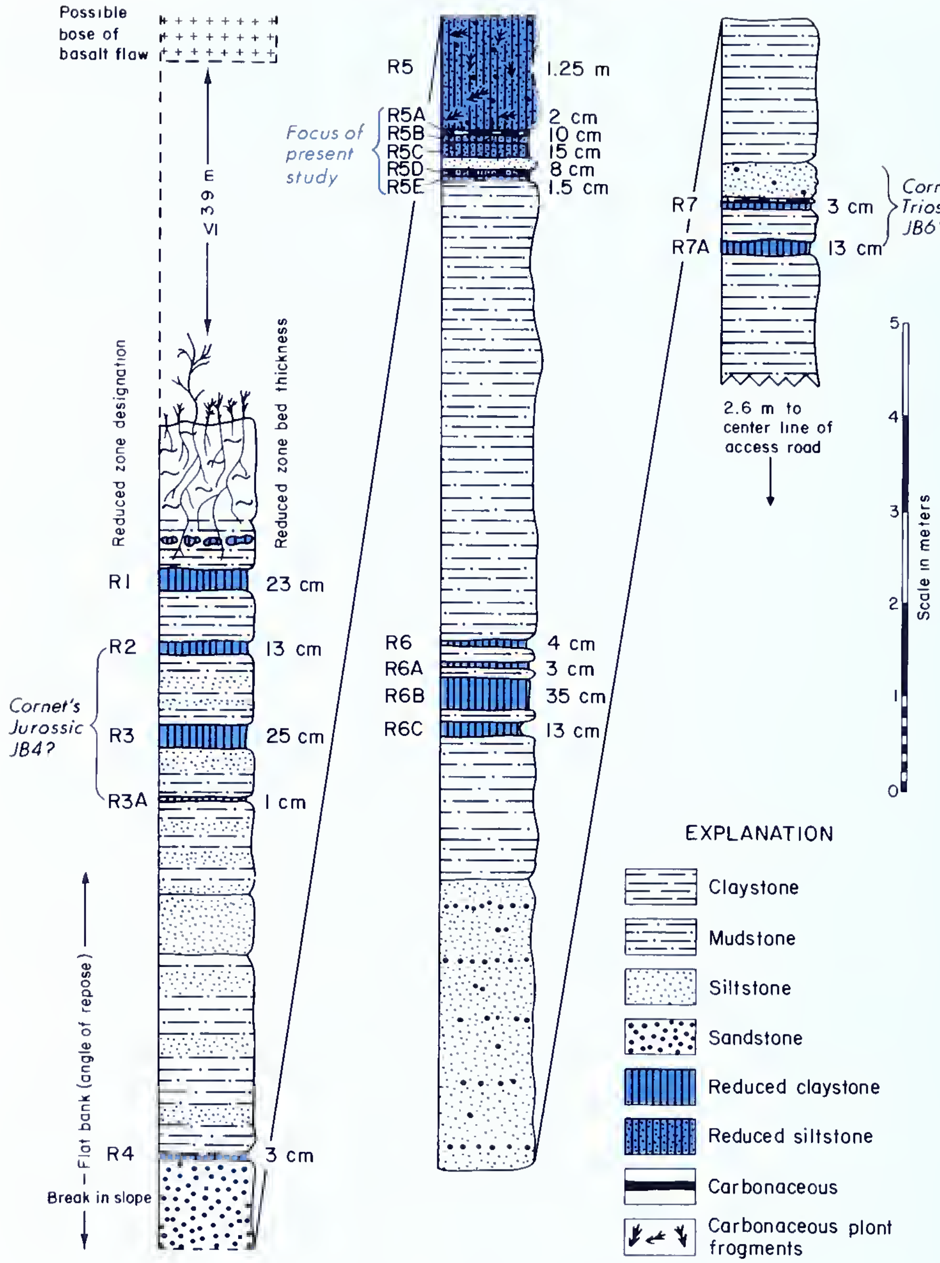

Figure 1. Stratigraphic section of the Mesozoic rocks beneath the Jacksonwald basalt flow. This exposure, a hand-dug trench on the north side of an east-west-trending access road approximately 415 m east of Antietam Creek, and approximately 1.4 km south-southeast of Jacksonwald, is believed to be near a similar exposure described by Cornet (1977). It is in the northwest quarter of the Birdsboro 7.5-minute quadrangle, Exeter Township, Berks County, Pennsylvania, latitude 40°18′47″N, longitude 75°50′38″W. Bedding here trends N84°E, 55°N. All lithologies are reddish brown except those shown in color, which are gray reduced beds.

layer. The composition of R5A is given in Table 1, and partial analyses of layers R5A through R5E, obtained by a different analytical method, are shown in Table 2 for comparison. When data for R5A are compared to data for typical shale (the post-Archean average shale [PAAS] of Taylor and McLennan, 1985), SiO_2, Al_2O_3, MgO, "Fe_2O_3," MnO, TiO_2, P_2O_5, and eight relatively immobile trace elements are within ± 20 percent of average shale values (Table 1). In view of the range of compositions encompassed by normal shales, this appears to indicate a strong affinity with shale. However, CaO, Na_2O, Cs, and Sr are more than 20 percent deficient with respect to average shale, possibly suggesting loss during a late alteration of plagioclase to the presently observed smectite (clay). On the other hand, K_2O, B, Co, Cu, Pb, Rb, Sc, U, Y, Zn, and rare earths, especially Eu, are enriched more than 20 percent over typical shale (Table 1). The enrichment in Eu relative to typical shale suggests even another hypothesis, that R5A contained feldspar of volcanic origin derived from the mantle. Perhaps R5A represents a pre-York Haven diabase, alkali basaltic pyroclastic layer that at least locally disrupted the vegetation, accounting for the coaly upper portion. Boron (Wherry, 1910), Cu, Pb, and some Zn may be hydrothermally enriched from the Jacksonwald basalt. Alternatively, the rare-earth elements, plus Sc, Y, Au, Pt, and some Zn, may have been concentrated by plants such as the observed *Equisetum,* the modern genus of which is reported to accumulate Zn and possibly ppb-level Au (Cannon and others, 1968). Uranium, Cu, and possibly Pb may have been concentrated from oxidized to reduced beds by chloride-bearing groundwater shortly after sedimentation.

Although a meteorite impact is herein rejected, the role of volcanism is as yet uncertain. Modification of the original protolith by coaly plant material and, later, metal-bearing solutions is also likely. Samples of each of the reduced zones were provided to R. Litwin of the U. S. Geological Survey, and his studies of the pollen content are proceeding. At present it is apparent that we do not know much about either the nature of the Triassic-Jurassic boundary or about the low-temperature geochemistry and biogeochemistry of the platinum group metals and gold. The situation reminds us of an old Pennsylvania Dutch adage, "We get too soon old and too late smart."

Reviews of an early draft of this article by A. Froelich and R. Litwin of the U. S. Geological Survey are gratefully acknowledged.

Table 1. *Chemical Analysis of Sample R5A Compared with the Average Composition of Post-Archean Shales (PAAS)*

Component		R5A	PAAS[1]	R5A[2] / PAAS	
Symbol	Name	(percent)	(percent)		
SiO_2	Silicon dioxide	51.0	62.8	0.81	
Al_2O_3	Aluminum oxide	21.8	18.9	1.15	
CaO	Calcium oxide	.52	1.3	.40	↓
MgO	Magnesium oxide	2.38	2.2	1.08	
Na_2O	Sodium oxide	.13	1.2	.11	↓
K_2O	Potassium oxide	4.67	3.7	1.26	↑
"Fe_2O_3"	Iron oxide	7.36	7.2	1.02	
MnO	Manganese oxide	.13	.11	1.18	
TiO_2	Titanium dioxide	.96	1.0	.96	
P_2O_5	Phosphorus oxide	.16	.16	1.00	
LOI	Loss on ignition	10.8	6.0	1.80	↑
SUM		99.91	104.57		
		(ppm)	(ppm)		
Ag	Silver	.5			
As	Arsenic	46			
Au	Gold	.022			
B	Boron	320	100	3.20	↑
Ba	Barium	670	650	1.03	
Be	Beryllium	5			
Br	Bromine	17			
Cd	Cadmium	2.0			
Co	Cobalt	33	23	1.43	↑
Cr	Chromium	110	110	1.00	
Cs	Cesium	9.2	15	.61	↓
Cu	Copper	150	50	3.00	↑
Ge	Germanium	< 10	1.4		
Hf	Hafnium	4	5.0	.80	
Mo	Molybdenum	< 5	1.0		
Nb	Niobium	20	19	1.05	
Ni	Nickel	61	55	1.11	
Pb	Lead	170	20	8.50	↑
Rb	Rubidium	200	160	1.25	↑
Sb	Antimony	3.3			
Sc	Scandium	21.2	16	1.33	↑
Se	Selenium	< 5			
Sr	Strontium	100	200	.50	↓
Ta	Tantalum	1			
Th	Thorium	12	14.6	.82	
U	Uranium	7.5	3.1	2.42	↑
V	Vanadium	180	150	1.20	
W	Tungsten	< 3	2.7		
Y	Yttrium	40	27	1.48	↑
Zn	Zinc	1,000	85	11.76	↑
Zr	Zirconium	180	210	.86	
La	Lanthanum	55.3	38	1.46	↑
Ce	Cerium	105	80	1.31	↑
Nd	Neodymium	53	32	1.66	↑
Sm	Samarium	11.7	5.6	2.09	↑
Eu	Europium	2.7	1.1	2.45	↑
Tb	Terbium	1.7	.77	2.21	↑

Table 1. *(Continued)*

Component		R5A (ppm)	PAAS[1] (ppm)	R5A[2]/PAAS	
Symbol	Name				
Yb	Ytterbium	4.1	2.8	1.46	↑
Lu	Lutetium	.64	.43	1.49	↑
Os	Osmium	<.003			
Ir	Iridium	<.0001			
Ru	Ruthenium	<.005			
Rh	Rhodium	<.001			
Pt	Platinum	.025			
Pd	Palladium	<.005			
Re	Rhenium	<.005			

[1] Estimate of average composition of post-Archean shales from Taylor and McLennan (1985, p. 28).

[2] Ratio of sample R5A to the composition of the average post-Archean shale (PAAS), indicating the degree to which each component is relatively enriched or deficient in this sample. Those for which R5A is enriched by more than 20 percent are indicated by an upward arrow (↑), and those for which R5A is deficient by more than 20 percent are indicated by a downward arrow (↓).

Table 2. *Selected Trace-Element Data for Each of the Beds in the R5 Zone at Jacksonwald, Berks County*

(Quantities are in parts per million)

Sample	Vanadium (V)	Chromium (Cr)	Manganese (Mn)	Iron (Fe)	Cobalt (Co)	Nickel (Ni)	Copper (Cu)	Zinc (Zn)	Gold (Au)
R5A	40	44	860	38,000	33	47	130	910	0.015
R5B	20	27	120	44,000	10	17	144	170	.010
R5C	15	23	160	26,600	10	29	97	168	.006
R5D	25	21	225	26,500	18	24	134	154	.004
R5E	20	29	194	28,000	14	35	116	186	.005

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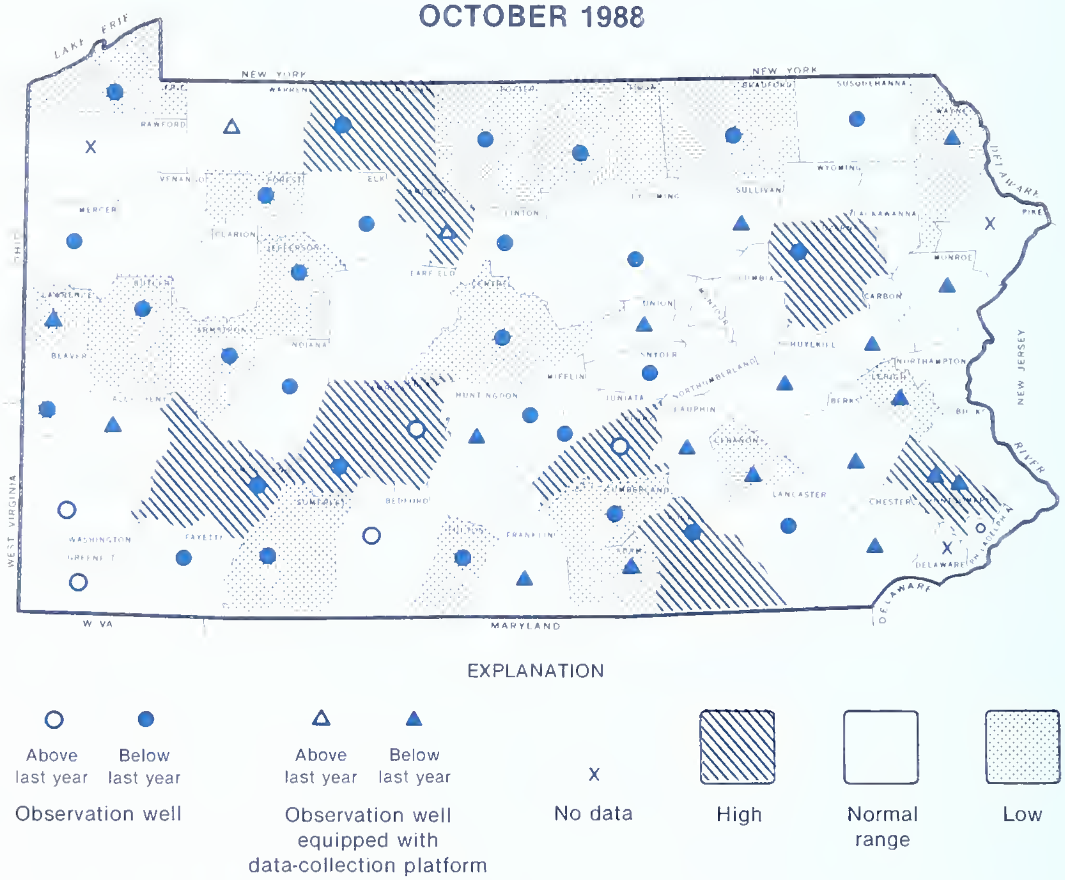

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